GEOLOGY OF THE
RY MOUNTAIN QUADRANGLE,
NYO COUNTY, CALIFORNIA

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CONTENTS

Page

ABSTRACT v

INTRODUCTION 1

PALEOZOIC STRATIGRAPHY 2
  Wood Canyon Formation 2
  Zabriskie Quartzite 2
  Carrara Formation 2
  Bonanza King Formation 2
  Nopah Formation 3
  Dunderberg Shale Member 3
  Upper Nopah Formation Undifferentiated 4
  Pogonip Group 4
  Lower Pogonip Group Undifferentiated 4
  Antelope Valley Limestone 5
  Eureka Quartzite 6
  Ely Springs Dolomite 6
  Hidden Valley Dolomite 6
  Lost Burro Formation 7
  Tin Mountain Limestone 8
  Perdido Formation 8
  Rest Spring Shale 9
  Keeler Canyon Formation 10
  Owens Valley Formation 10

CENOZOIC ROCKS 10
  Volcanic Rocks of the Saline Range 10
  Older Alluvial Deposits 11
  Basalt 11
  Landslide Deposit 11
  Lake Deposits 12
  Spring Deposits 12
  Talus Deposits 12

INTRUSIVE IGNEOUS ROCKS 12
  Hunter Mountain Quartz Monzonite 12
  Dikes and Sills 13

STRUCTURE 13
  Panamint Range 13
  Last Chance Range 13
  Saline Range 16
  Extent and Age of Thrusting 16

REFERENCES 19

CONTENTS—Continued

Illustrations

			Page
Plate	1.	Geologic map and sections of the Dry Mountain quadrangle	In pocket
Figure	1.	Index map	1
Figure	2.	Whitening of dolomite in Bonanza King Formation	3
Figure	3.	Characteristic thick band in upper Nopah Formation	4
Figure	4.	Nopah Formation, lower Pogonip Group and lower Antelope Valley Limestone near Teakettle Junction	5
Figure	5.	Complete section of rocks exposed in cliff face	5
Figure	6.	Contrasting limestone bands in Lost Burro Formation	7
Figure	7.	Contact between Lost Burro Formation and Tin Mountain Limestone	8
Figure	8.	A rare normal contact between upper Perdido formation and Rest Spring Shale	9
Figure	9.	Basal boulder beds of older alluvium	12
Figure	10.	Disharmonic recumbent syncline in Keeler Canyon Formation	14
Figure	11.	Disharmonic folds in upper Lost Burro Formation	15
Figure	12.	Highly deformed Lost Burro Formation	15
Figure	13.	Wedge of Hunter Mountain Quartz Monzonite thrust over Keeler Canyon Formation	17
Figure	14.	Contact between overturned Owens Valley Formation and quartz monzonite stock	18
Figure	15.	Eureka Quartzite thrust over upper part of Lost Burro Formation	18

ABSTRACT

More than 19,000 feet of Paleozoic rocks crop out in the Dry Mountain quadrangle. The lower 2,000 feet of section is composed of predominantly clastic quartzose sediments, whereas the remainder of the section is mostly limestone and dolomite with only three thin clastic formations intercalated—the Dunderberg Shale Member of the Nopah Formation (Upper Cambrian), the Eureka Quatzite (Ordovician), and the Rest Spring Shale (Mississippian ?). Cenozoic volcanic rocks, both basic (basalts) and felsic in composition, form extensive outcrops in the western and southern parts of the quadrangle.

Two east-directed thrust faults form the most important structural elements in the Dry Mountain quadrangle. A small part of the Racetrack thrust of McAllister (1952) is exposed in the southeast part of the area. Most of the Paleozoic rocks of the Saline Range are allochthonous and are part of a very extensive thrust plate that is exposed in northern Last Change Range, Saline Range, and eastern Inyo Mountains. Potassium-argon ages determined from quartz monzonite and syenite stocks, which cut these thrust plates, indicate the thrusting occurred prior to the Late Jurassic and after Early Permian time.

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EOLOGY OF
HE DRY MOUNTAIN QUADRANGLE,
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B. CLARK BURCHFIEL

INTRODUCTION

The Dry Mountain quadrangle lies within the Great in physiographic province in Inyo County, south- tern California (fig. 1). The western boundary of ath Valley National Monument trends north-south ough the center of the quadrangle. All the drain- is intermittent and ends in interior valleys draining theast into Death Valley and south into Saline and cetrack Valleys. Rising from 1100 feet in Saline lley to 8674 at Dry Mountain, the southern part the Last Chance Range forms the main mountain- mass in the quadrangle. To the west, across upper Saline Valley, the eastern part of the Saline Range rises higher than 7000 feet. In the southeast corner of the quadrangle lies part of the western slope of the northern Panamint Range.

The principal published studies that cover adjoining or nearby areas are McAllister (1952 and 1956), Merriam and Hall (1957), Merriam (1963a), Hall and McKevett (1962) and Hall and Stephens (1962).

Work on the present report was conducted intermittently from 1963 through 1965; approximately 110 days were spent in field work. The writer was assisted in the field by John Bennett, Gregory Davis, John McCrevey, and Raymond Wilson. Funds to conduct

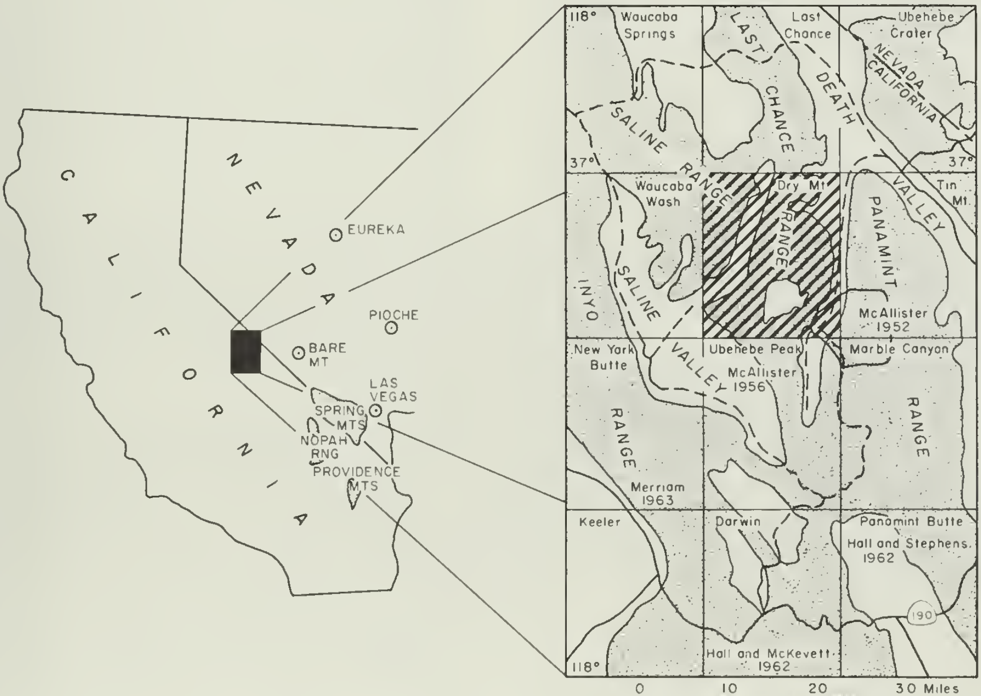


Figure 1. Index map shows location of the Dry Mountain quadrangle and adjacent quadrangle sheets.

the research were contributed by National Science Foundation Grant GP 1154.

PALEOZOIC STRATIGRAPHY

Paleozoic rocks in the Dry Mountain quadrangle range in age from Early Cambrian to Permian. More than 19,000 feet of Paleozoic rocks are exposed, but the top and bottom of the sequence is not exposed. Formational subdivision of the rocks in the Last Chance Range follows, for the most part, the well-known subdivisions of the Death Valley region. Rocks in the Saline Range at the west side of the quadrangle show similarities to both the Death Valley stratigraphy and the more recently described stratigraphy of the Inyo Mountains (Nelson, 1962, and Ross, 1965). The Death Valley subdivisions are used here because of the writer's greater familiarity with them.

Wood Canyon Formation

The Wood Canyon Formation was first described by Nolan (1929) from exposures in the Spring Mountains 80 miles east of the Dry Mountain quadrangle. Rocks belonging to the Wood Canyon Formation are exposed in the Saline Range, where only the upper 500 feet of the formation is present along the western boundary of the quadrangle. The rocks consist of brown and red weathering quartzite and green to brown siltstone and shale. Some brown and gray limestone beds are present in the uppermost Wood Canyon. Numerous studies (e.g., Nolan, 1929, and Hunt and Mabey, 1966) have demonstrated that the upper part of the Wood Canyon Formation is Early Cambrian in age.

Zabriskie Quartzite

The Zabriskie Quartzite was originally defined by Hazzard (1937) as a member of the Wood Canyon Formation and was redefined by Wheeler (1948) as a formation, as it is used here. A complete section of Zabriskie Quartzite is present along the western boundary of the quadrangle, and an incomplete section of Zabriskie is present near the east side of the quadrangle in the low hills 4½ miles east of Dry Mountain. The Zabriskie consists of approximately 250 feet of pink, white and brown, fine- to coarse-grained quartzite. The rocks are medium- to thick-bedded and are commonly well laminated and cross-bedded. Rare worm (?) tubes of the type called *Scolithus* appear near the middle of the formation. Numerous studies have demonstrated (e.g., Hazzard, 1937, and Hunt and Mabey, 1966) that the Zabriskie Quartzite is Early Cambrian in age.

Carrara Formation

The Carrara Formation was named by Cornwall and Kleinhampl (1961) for exposures at Bare Mountain, Nevada. The Carrara Formation crops out only in the low hills 4½ miles east of Dry Mountain, where it is badly faulted, and along the western boundary of the quadrangle in the Saline Range. The eastern outcrops of the Carrara consist of green shale and thin-bedded limestone, with a few thin beds of quartzit near the base. These beds are transitional through zone about five feet thick into the thin-bedded quartzite of the upper part of the Zabriskie Quartzite. In th Saline Range, quartzite is much more abundant in th lower part of the Carrara, but the contact with th Zabriskie Quartzite is still reasonably sharp.

East of Dry Mountain, the lower 600 feet of th Carrara Formation is composed of interbedded gree and brown shale,. orange-weathering silty limestone gray to dark gray coarse-grained limestone, and brow calcareous sandstone and quartzite. The limestone bed range in thickness from six inches to two feet and ma be grouped into ledge-forming limestone units up t 40 feet thick. Algal (?) pisolites up to two inches i diameter are common in the limestones. Overlying th basal shales are 900 feet of Carrara rocks containin two distinct limestone units. The lower limestone uni is about 250 feet thick and consists of dark gray thick bedded coarse- to medium-grained limestone containing pisolites. Orange-weathering silty limestone present at the top and bottom of this unit and grade into the green shale below and red, brown and gree shaly siltstone above. The upper limestone unit is abou 200 feet thick, consisting of gray and light-gray limestone and dolomite. A prominent cream-colored ban of dolomite occurs near the top.

In the Saline Range, the upper 1000 to 1200 feet the Carrara Formation contains more limestone tha the section east of Dry Mountain; a 600-foot unit dark gray limestone is present above the basal quart ites and shales. The remaining upper part of th Carrara consists of green and brown shale, with thi interbeds of limestone, overlain by orange-weatherin silty limestone that grades upward into the overlyin Bonanza King Formation above the upper limesto unit.

Both Early and Middle Cambrian fossils have be found in the Carrara Formation in other parts of Ca fornia and Nevada (A. R. Palmer, personal comm 1964); thus, the Early-Middle Cambrian boundary fa within the Carrara Formation. Many of the san limestones contain trilobite remains in the Dry Mou tain quadrangle, but no identifiable fossils were c lected.

Bonanza King Formation

The Bonanza King Formation was named and d scribed by Hazzard and Mason (1936) from exposu in the Providence Mountains, California. Palmer a Hazzard (1956) re-evaluated the age originally signed to the Bonanza King Formation and demo strated that it embraces all the rocks between the Du derberg Shale Member of the Nopah Formation a the Carrara Formation, or their equivalents; it is this context that the name is presently used. McAllis (1952 and 1956) used the name Racetrack Dolom for the part of these rocks near Teakettle Junctio The Racetrack Dolomite contains only the upper p of the sequence of rocks mapped here as Bonanza Ki Formation.

In the Saline Range the contact between the Bonanza King Formation and the underlying Carrara Formation is transitional. The basal beds of the Bonanza King are interbedded with silty and orange-weathering limestones that grade downward into the orange-weathering limestone and calcareous siltstone of the upper Carrara Formation. The upper contact of the Bonanza King with the Dunderberg Shale is sharp. Gray and dark gray dolomite beds of the Bonanza King are overlain by 10 feet of dark brown sandy imestone and brown shale of the Dunderberg.

The Bonanza King Formation can be divided into wo units by the presence of 50 feet of yellow- to range-weathering silty dolomite that occurs about 700 feet above the base of the formation (pl. 1). The ower unit consists of interbedded light gray, gray, nd dark gray dolomite that occasionally contains enses of chert. Bedding is distinct on weathered suraces, and thin laminations are commonly present. Much of the formation shows mottling of gray and ark gray dolomite. Thin beds of yellow- and orange-weathering silty dolomite are characteristic of the ower unit. The upper unit consists of approximately 600 feet of gray and dark gray dolomite with occaonal beds of cream colored dolomite; the interbeding causes a distinct color banding in the upper unit f the Bonanza King. One mile west of Teakettle unction, the Bonanza King Formation is in contact ith the Hunter Mountain Quartz Monzonite, and the olomite has been metamorphosed to a very coarse-rained white dolomite for about 400 feet from the ontact (fig. 2). This whitening is common near trusive bodies in the Dry Mountain quadrangle and uch of the surrounding region.

The Bonanza King Formation probably is both iddle and Late Cambrian because it is overlain by e Late Cambrian Dunderberg Shale Member of the opah Formation and underlain by the Middle Camian Carrara Formation. The two units present in the Bonanza King are very similar lithologically to the Banded Mountain and Papoose Lake Members of the Bonanza King Formation described by Barnes and Palmer (1961) from exposures in the Nevada Test Site.

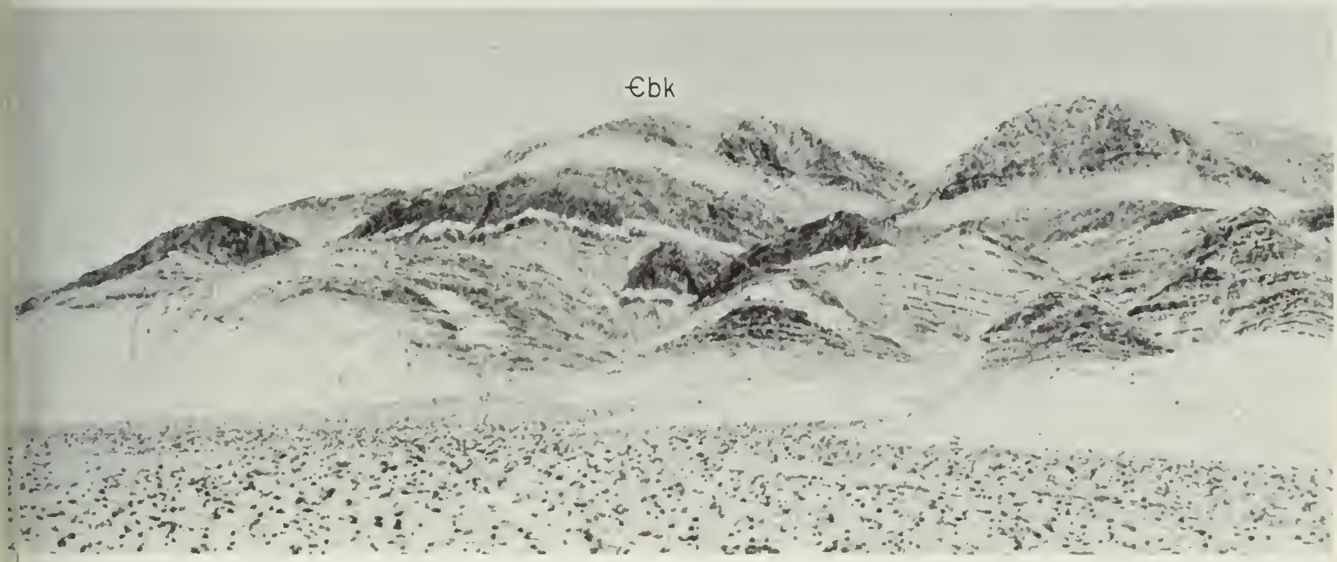
Nopah Formation

Hazzard (1933) defined the Nopah Formation from exposures in the Nopah Range of southeastern California. The Nopah Formation is subdivided into two mappable units in the Dry Mountain quadrangle. The lower 150 feet of shale in the Nopah Formation is mapped as the Dunderberg Shale Member. In eastern Nevada the Dunderberg Shale is mapped as a separate formation first described by Hague (1883) as the Hamburg Shale and later renamed the Dunderberg Shale by Walcott (1908). All the rocks overlying the Dunderberg Shale Member are mapped as the upper Nopah Formation undifferentiated. These rocks could be further subdivided; however, this was not done, and a formal member designation is not used in this report.

Dunderberg Shale Member

The Dunderberg Shale Member of the Nopah Formation consists of brown and green shale with thin beds of gray limestone. The lower 75 feet of the Dunderberg Member is predominantly brown shale. Fine-grained, gray limestone with wavy bedding surfaces and thick beds of coarse-grained brown-weathering bioclastic limestone are rare. In the upper 75 feet of the Dunderberg, the limestone beds become more common until, near the top, the formation is composed mainly of limestone, with thin calcareous siltstone partings that form a gradational contact with the overlying upper Nopah Formation undifferentiated.

The shales commonly contain numerous phosphatic brachiopods, and the limestones contain numerous fragments of trilobites. McAllister (1952) made collections from rocks near the base of the Nopah Formation that are probably equivalent to the rocks



gure 2. Dark gray dolomite whitens at the toe of the spurs in th view of the Bonanza King Formation (Ꞓbk), half a mile west of Teakettle Junction. Part of the Hunter Mountain igneous complex crops out in the foreground pediment.

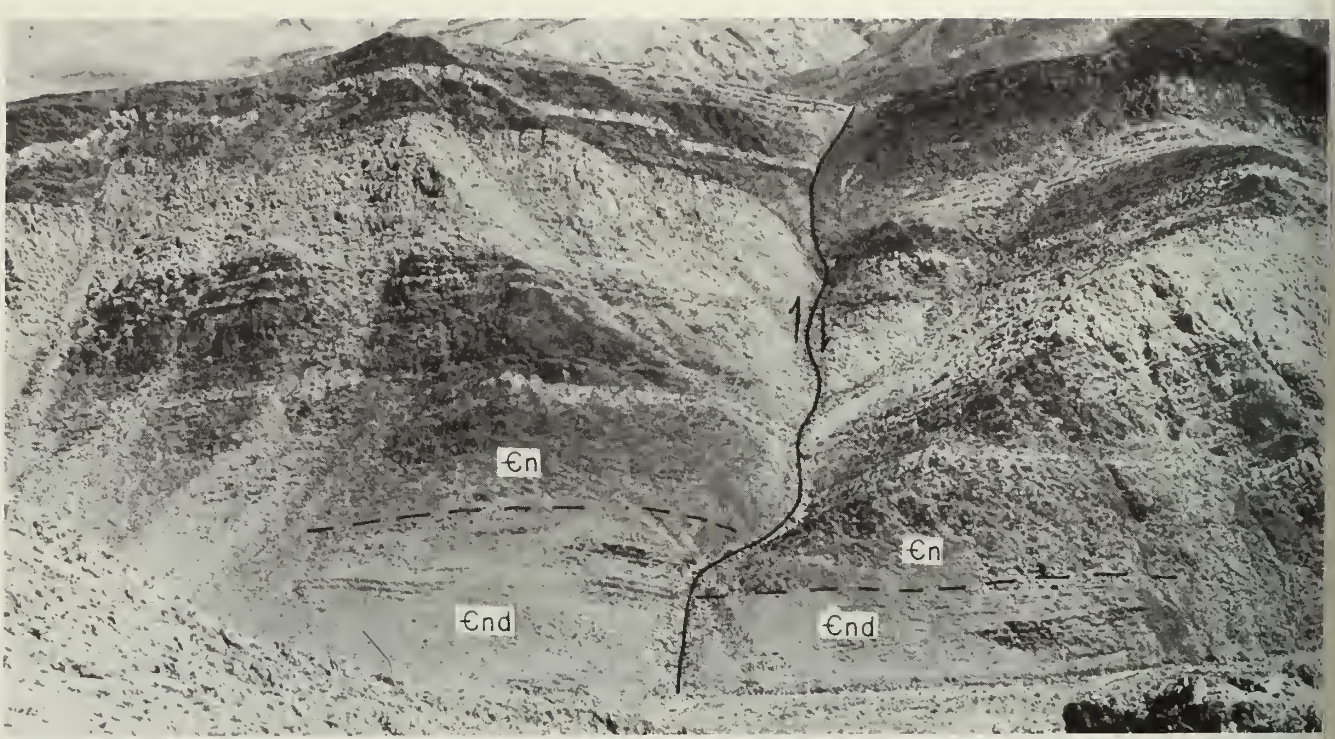


Figure 3. The lower part of the upper Nopah Formation (Ꞓn) shows the characteristic thick cream-colored band. The basal Dunderberg Shale Member (Ꞓnd) crops out at the base of the cliff.

mapped as the Dunderberg Shale Member here. His fossil collection came from rocks 1 to 1½ miles north of Teakettle Junction. Palmer (1965) indicates that both the *Elvinia* and *Dunderbergia* Zones are present in these shaly rocks. Palmer's data add direct support to the correlation of the Dunderberg Shale Member of Dry Mountain quadrangle with the type Dunderberg Shale.

Upper Nopah Formation Undifferentiated

The upper undifferentiated part of the Nopah Formation can be subdivided into two distinct lithologic units. The lower unit consists of about 250 to 300 feet of thin-bedded orange-weathering silty limestone and interbedded dark gray limestone, commonly with cherty lenses and nodules. These rocks are transitional with the underlying Dunderberg Shale Member. The upper unit of the Nopah undifferentiated consists of 1,300 feet of thick-bedded cliff-forming dolomite.

The upper unit is characterized by distinct color-banding of dark gray and white or cream-colored dolomite similar to some parts of the Bonanza King Formation. One of the cream-colored bands is about 200 feet thick and forms a distinctive band in the lower part of this unit (fig. 3). The contact with the overlying Pogonip Group is conformable and gradational. The upper dark-gray dolomite of the upper Nopah Formation undifferentiated contains thin silty layers, and the dolomite becomes thinner bedded and weathers medium to light gray grading into the rocks of the basal lower Pogonip Group. From a distance, the contact is easily mapped because it is marked by a change in slope from the dark gray cliffs of the Nopah Formation to the light gray slopes of t
Pogonip Group; but in detail the contact is grad
tional through about 10 feet of strata.

McAllister (1952) found high Late Cambrian foss
in the upper half of the Nopah undifferentiated abo
one mile north of Teakettle Junction. On this bas
the upper Nopah Formation undifferentiated is a
signed to the Late Cambrian. The upper and low
units are lithologically similar to rocks in the Neva
Test Site that have been mapped as the Smoky a
Halfpint Members of the Nopah Formation (Barn
and Christiansen, in press).

Pogonip Group

The name Pogonip was first used by King (187
in central Nevada for all the rocks between the ba
Cambrian quartzites and the Eureka Quartzite. Sin
then, the unit has been redefined and the name
presently applied to a group, in accord with a pr
posal by Hintze (1951). At Eureka, Nevada, t
group has been divided into three formations: Ant
lope Valley Limestone, Ninemile Formation, a
Goodwin Limestone. Ross (1964b) recognized th
at Dry Mountain, the lower two formations a
mapped in this report as the lower Pogonip Gro
undifferentiated.

Lower Pogonip Group Undifferentiated

The lower 600 feet of the lower Pogonip Gro
undifferentiated consists of medium gray dolom
with rare beds of limestone near the base and contai
interbedded light-gray and medium-gray limesto
and dolomite near the top (fig. 4). Throughout t
formation are thin beds of silty, orange-weatheri

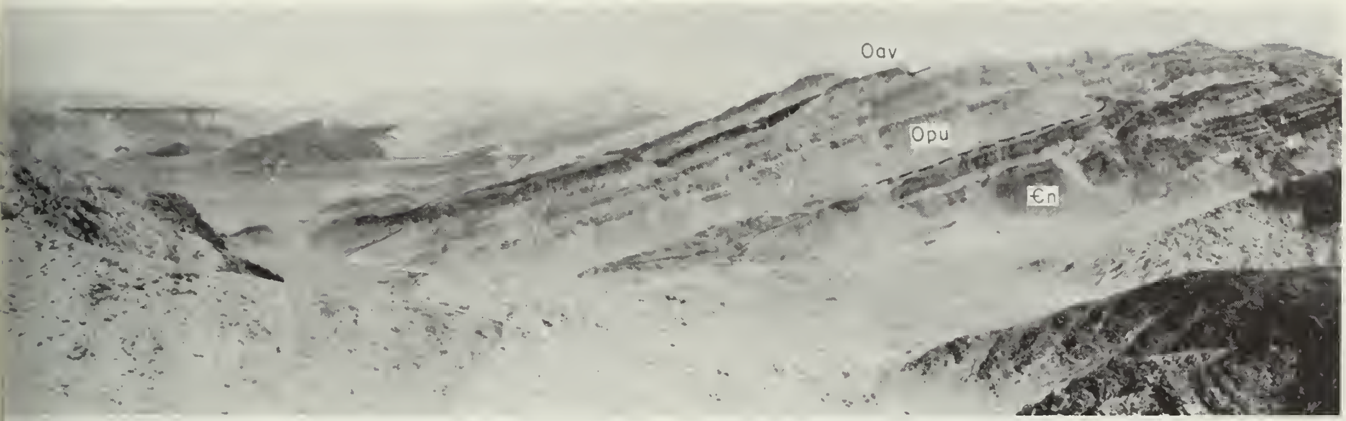


Figure. 4. In this westward view, the Napah Formation (€n) is verlain by the lower Pogonip Group undifferentiated (Opu) and the lower Antelope Valley Limestone (Oav). The locality is three and one-half miles northwest of Teakettle Junction.

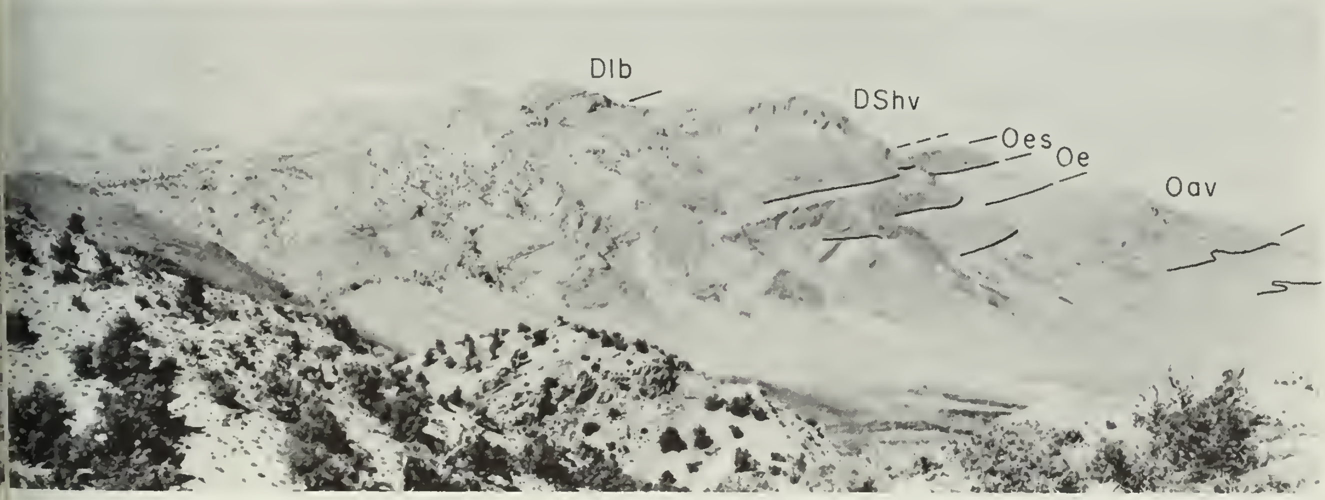
olomite. The basal part of these dolomites contains nses of chert and crops out only in the hills two iles north of Teakettle Junction.

The upper 150 feet of the lower Pogonip Group ndifferentiated consists of silty orange-weathering mestone and shale that correspond to unit 5 of IcAllister's measured section (1952, p. 11). These ocks are well exposed in the southeast part of the uadrangle three miles north of Teakettle Junction ig. 4). Ross (1964b) describes late Early Ordovician ossils from these rocks 1½ miles north of Teakettle unction. These fossils are the same size as those he ound in his zone "J" in Utah. Zone "J" fossils are esent in the Type Ninemile Formation near Eureka, evada, with which these shaly rocks are correlated.

Antelope Valley Limestone

The Antelope Valley Limestone was first defined Nolan and others (1956). The rocks assigned to e Antelope Valley Limestone in the Dry Mountain uadrangle lie in a stratigraphic position similar to that at Eureka, Nevada, where the rocks lie above the Ninemile Formation and below the Eureka Quartzite. Four lithologic units can be recognized in the Antelope Valley Limestone (pl. 1). The lowermost unit consists of cherty and siliceous limestone, which is thinly bedded but weathers into a massive 200-foot cliff between two silty and shaly slope-forming units (fig. 4). The cliff is characterized by a deep red-brown weathered surface.

Brown- and yellow-weathering shaly limestone and silty limestone form the second unit of the Antelope Valley Limestone. The rocks are thin bedded with wavy bedding surfaces that make the beds look like rows of nodules. This second unit varies in thickness, from less than 50 feet in the southern part of the quadrangle to more than 200 feet in the northern part. The third unit forms a massive 600-foot cliff of dark gray thick-bedded limestone occasionally interbedded with thin silty partings (fig. 5). Unit four, the uppermost unit, consists of 25 to 30 feet of orange-weathering sandy limestone and siltstone that is overlain by the Eureka Quartzite above a sharp contact.



gure 5. This cliff face exposes a conformable section of rocks (= Antelope Valley Limestone, Oe = Eureka Quartzite, Oes = Ely S ngs Dolomite, DShv = Hidden Valley Dolomite, Dlb = Lost Burro Formation). The view is north across a large reentrant valley near the north end of the Dry Mountain quadrangle.

The middle part of unit three contains numerous *Maclurites*, *Palliseria* and *Receptaculites* characteristic of the Antelope Valley Limestone throughout the Great Basin. Assignment of Middle Ordovician age to the Antelope Valley Limestone is based on observations of similarly-dated fossils in the middle and upper parts of the limestone and date Early Ordovician fossils in underlying rocks. A peculiarity of the Antelope Valley in the Dry Mountain quadrangle is the presence of a prominent shaly limestone unit (second unit) within the formation that is not present in the Specter Range, Nevada, farther east (Burchfiel, 1964).

Eureka Quartzite

The Eureka Quartzite redefined by Kirk (1933) is one of the most widespread and distinctive formations in the Great Basin. Consisting of about 450 feet of quartzite, it forms a conspicuous break in the predominantly carbonate Paleozoic sequence. The Eureka can be crudely divided into upper and lower units of about equal thickness. The lower unit consists of brown-, yellow-, and red-weathering fine- to medium-grained quartzite. Bedding is generally indistinct, but differential weathering brings out the thin- to medium-bedded, sometimes cross-bedded, character of the quartzite. The upper unit is similar to the lower unit except that it weathers white and is usually more vitreous. Both units show quartz overgrowths on rounded quartz grains. Contacts between both adjacent formations and the Eureka Quartzite are sharp; the Eureka is overlain by sandy black dolomite of the Ely Springs Dolomite and underlain by sandy orange-weathering siltstone of the upper Antelope Valley Limestone. In many places the lower contact is slickensided, indicating movement has occurred along the bedding planes at the contact.

Fossils are rare in the Eureka Quartzite throughout the Great Basin, but in some areas fossiliferous limestone is present in the Eureka. Most recent workers assign the Eureka to the upper part of the Middle Ordovician (Porterfield, Wilderness and lower Barnveld Stages as defined by Ross, 1964a).

Ely Springs Dolomite

The Ely Springs Dolomite was first described by Westgate and Knopf (1932) from exposures in the Pioche district, Nevada. The Ely Springs Dolomite is easily identified, because the lower part forms a dark black band above the white Eureka Quartzite. Rocks mapped as Ely Springs Dolomite in the Dry Mountain quadrangle are stratigraphically equivalent to those mapped as Ely Springs by McAllister (1952 and 1956).

Two units can be recognized in the Ely Springs Dolomite. The lower unit is approximately 500 feet thick and consists of dark gray to black, coarse-grained, thick-bedded dolomite. Chert nodules are common in the lower part along with corals, irregular algal (?) structures and pisolites. Four miles north of Teakettle Junction the Ely Springs contains a 10-foot bed of calcareous quartzose sandstone 20 feet above the base. The sandstone is certainly a lens as it cannot be traced far before it pinches out. The uppe unit is about 150 to 200 feet thick and consists o medium-bedded, gray to light-gray dolomite with n chert. Cherty gray dolomite of the lower Hidde Valley Dolomite overlies the upper unit. In the low hills two to four miles north of Teakettle Junction faulting and brecciation are extreme, and it was impossible to separate the gray dolomite of the uppe Ely Springs Dolomite from that of the Hidden Valle Dolomite; thus, the upper contact was drawn at th top of the dark gray dolomite of the lower unit.

The Ely Springs Dolomite contains a few coral that were indeterminate. McAllister (1952) collecte Late Ordovician fossils from the Ely Springs abou two miles south of the Dry Mountain quadrangl Recent work by Ross (1964a), in a regional study o the Lower and Middle Ordovician rocks in the Grea Basin, indicates that the lower Ely Springs Dolomit of Teakettle Junction contains an uppermost Middl Ordovician fauna.

Hidden Valley Dolomite

The name Hidden Valley Dolomite was first use by McAllister (1952, p. 15) for exposures along th east side of Hidden Valley four miles southeast o the Dry Mountain quadrangle. Good outcrops of th Hidden Valley Dolomite are present along the eas side of the Last Chance Range at the north end o the quadrangle, where the dolomite is approximatel 1300 feet thick.

The contact between the Hidden Valley Dolomit and the underlying Ely Springs Dolomite is place at the base of a prominent chert-bearing dolomit that usually corresponds to a subtle color change fro light-gray below to medium-gray above. In the southern part of the quadrangle the chert is present nodules and lenses through about 150 feet of sectio but at the north end of the quadrangle the lenses begi to coalesce and form a ledge of nearly solid che approximately 100 feet thick. In the badly faulted hil two to four miles north of Teakettle Junction, t lower contact was placed at the top of the prominen black dolomite in the Ely Springs Dolomite. T cherty unit is present in this area, but the rocks a so badly brecciated that it was not easy to separa the medium gray dolomite of the lower Hidden Va ley from the light gray dolomite of the upper E Springs. The upper contact between the Hidd Valley Dolomite and the Lost Burro Formation drawn at the base of a vitreous white quartzite. McA lister's original definition included some cherty dol mite below the sandstone near the base of the Lo Burro Formation. In the Dry Mountain quadrang the cherty beds are not always well developed, a the base of quartzose sandstone was selected as t basal contact because it is conspicuous and easi mapped.

The Hidden Valley Dolomite can be divided in three units that are probably equivalent to those McAllister (1952). The lower unit, approximately 5 feet thick, consists of medium-bedded fine-grain gray and light gray dolomite, with abundant che lenses and layers in the lower 150 feet. The low unit forms medium-gray skree-covered slopes below the massive middle unit at the north end of the quadrangle. The middle unit, approximately 600 feet thick, consists of a cliff-forming light-gray weathering thick-bedded dolomite. The upper unit consists of 200 feet of medium-bedded, fine-grained, medium to dark gray dolomite that commonly weathers gray-brown to olive. Occasional lenses of chert are present throughout the upper unit.

Silurian fossils (*Halysites* and *Favosites*) are present about 200 feet above the base of the Hidden Valley Dolomite. McAllister (1952) found similar fossils at about the same horizon, and he also found Lower Devonian fossils of the *Spirifer kobehana* Zone in the upper unit near the top of the Hidden Valley. The upper unit is lithologically similar and contains the same faunal zone as the Beacon Peak Dolomite Member of the Nevada Formation near Eureka, Nevada (Nolan and others, 1956). The Hidden Valley Dolomite probably embraces all the Silurian and some Lower Devonian rocks in the Dry Mountain quadrangle.

Lost Burro Formation

The Lost Burro Formation was named by McAllister (1952) for exposures at Lost Burro Gap ¼ mile south of the Dry Mountain quadrangle. The 1600 feet of rocks mapped as the Lost Burro Formation in the present report are continuous with rocks mapped by McAllister (1956) as the Lost Burro in the Ubehebe Peak quadrangle to the south. The limestone and dolomite of the Lost Burro Formation crop out extensively in the central part of the quadrangle and form the axis of the southern Last Chance Range.

The base of the Lost Burro Formation is placed at the base of a bed of vitreous white occasionally dolomitic quartzite that is 10 to 15 feet thick but thickens to 50 to 60 feet at the north end of the quadrangle. Above the quartzite is 300 to 500 feet of light-gray medium- to thick-bedded dolomite interbedded with dark gray and black dolomite and limestone, a section that gives the lower part of the Lost Burro Formation a weakly banded appearance. The upper 1100 to 1300 feet of the formation is mainly gray and dark gray limestone with beds of light-gray dolomite and limestone, a section that gives the formation a characteristic banded appearance (fig. 6). Stromatoporids and cladoporids are common in the limestones.

Toward the north end of the quadrangle, the darker colors become less common and the entire Lost Burro Formation has a light gray aspect. Thin quartzite beds become common in the middle and upper parts of the formation. The top of the Lost Burro is placed at the top of a six-foot bed of white quartzite that sometimes weathers orange. Toward the west side of Dry

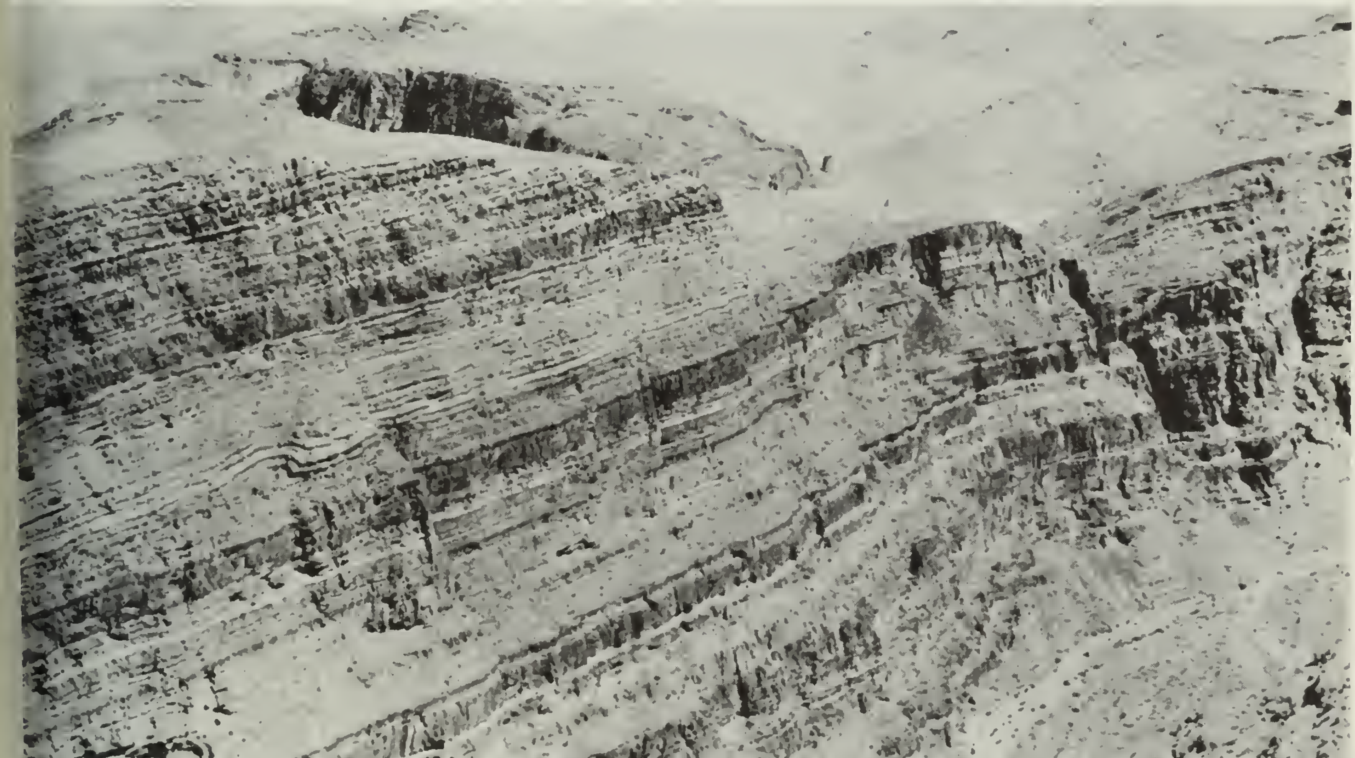


Figure 6. The typical Lost Burro Formation shows a strong color banding of gray and dark gray limestone.

Mountain, the quartzite is more dolomitic and in some places becomes sandy dolomite.

No fossils were collected from the Lost Burro Formation during this study. McAllister (1952, p. 19) collected fossils that belong to the *Cyrtospirifer* Zone of Late Devonian Age from the uppermost 35 feet of the Lost Burro Formation. At least part of the formation is Middle Devonian, since Merriam (1963a) found abundant *Stringocephalus* in the lower few hundred feet of the Lost Burro at Cerro Gordo, 15 miles southwest of Dry Mountain quadrangle.

The dolomite and quartzite in the lower part of the Lost Burro Formation are lithologically similar and correlate with the upper part of the Nevada Formation as defined by Merriam (1940, pp. 10–17). The Nevada Formation also contains *Stringocephalus* at the top. The remainder of the Lost Burro Formation correlates with the Devil's Gate Limestone, which overlies the Nevada Formation in the Eureka District and, like the upper Lost Burro, contains *Cyrtospirifer* at the top (Merriam, 1963b, p. 53).

Tin Mountain Limestone

McAllister (1952) defined the Tin Mountain Limestone on the basis of strata exposed three miles southeast of the Dry Mountain quadrangle. The Tin Mountain Limestone makes an excellent marker unit because of its distinctiveness in the upper part of the Paleozoic sequence (fig. 7). Two units can be recognized and both are well developed in the southern part of the quadrangle. The lower unit consists of 150 feet of thin-bedded gray limestone and interbedded calcareous shaly siltstone that weather pale pink, red and purple. The character of the lower unit varies throughout the quadrangle from yellow-weathering calcareous shale three miles west of Dry Mountain to yellow-weathering silty limestone with no shale in some areas of the south central part of the quadrangle. The upper unit is 250 feet thick and consists of thin- to medium-bedded coarse- to fine-grained dark gray limestone. Large horn corals and crinoid stems are abundant in the upper unit. Both the upper and lower units contain chert nodules, a distinctive characteristi of the Tin Mountain.

The thickness of the Tin Mountain Limeston varies from a maximum of about 420 feet to zer The Tin Mountain Limestone seems to thin towar the northwest, and, in some places along the west sid of the Last Chance Range, it is reduced to only a fe tens of feet of the lower unit. In one place, it appear to be completely absent as a result of pre-Perdid erosion. In the southern part of the quadrangle, th Tin Mountain appears to be conformably overlain b a thin unit of black argillite of the basal Perdido Fo mation; however, the regional thinning of the Ti Mountain suggests that here the upper contact is mo likely a disconformity.

McAllister (1952 and 1956) reports Lower Missi sippian fossils from the Tin Mountain Limestone. La genheim and Tischler (1960) and Merriam (1963 p. 18) made large fossil collections from the ty section of the Tin Mountain that also indicated a Early Mississippian age.

Perdido Formation

The name Perdido Formation was first used b McAllister (1952) for exposures in Perdido Cany 2½ miles east of Teakettle Junction. Rocks mappe as Perdido Formation in the Dry Mountain quadrang occupy the same stratigraphic position as the ty Perdido, but, since lithologic variations within the fo mation are common, the rocks are only grossly simil to those of the type section. The contact between t Perdido Formation and the underlying Tin Mounta Limestone is unconformable in the western part of t Last Chance Range. Rocks of the Perdido rest on varying thickness of Tin Mountain Limestone, in few places on the lower unit of the Tin Mounta and, in one place, apparently on the upper part of t Lost Burro Formation. Similar relations have be found in the Cerro Gordo area of the southern In Range by Merriam (1963a). In the southern part the quadrangle the lower contact appears conformab but is most likely disconformable.

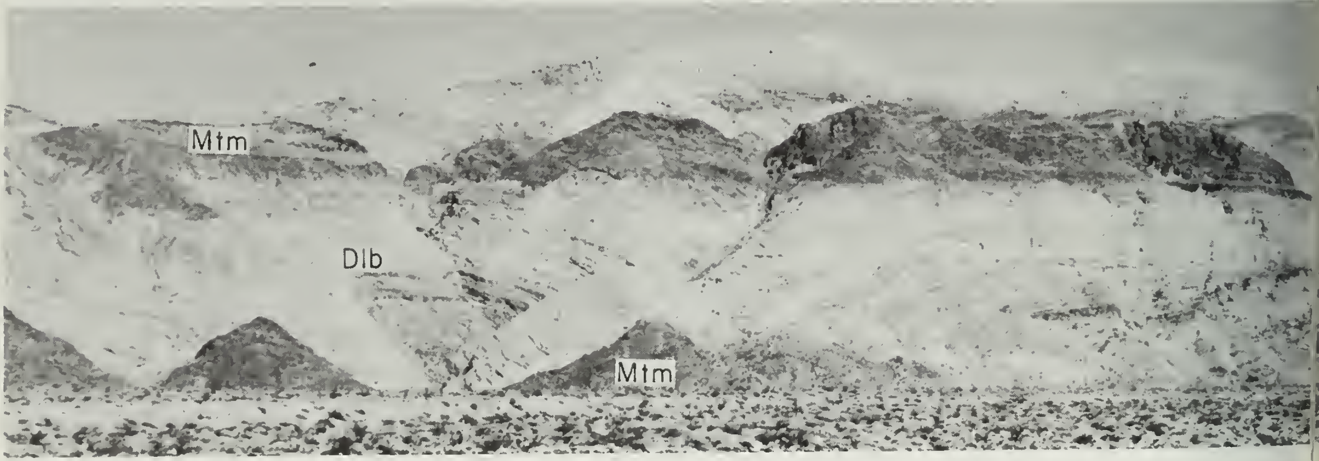


Figure 7. Excellent contrast between the Lost Burro Formation (Dlb) and the Tin Mountain Limestone (Mtm) exhibits this contact. The low dark hills at the base of the main ridge are downfaulted blocks of Mountain Limestone.

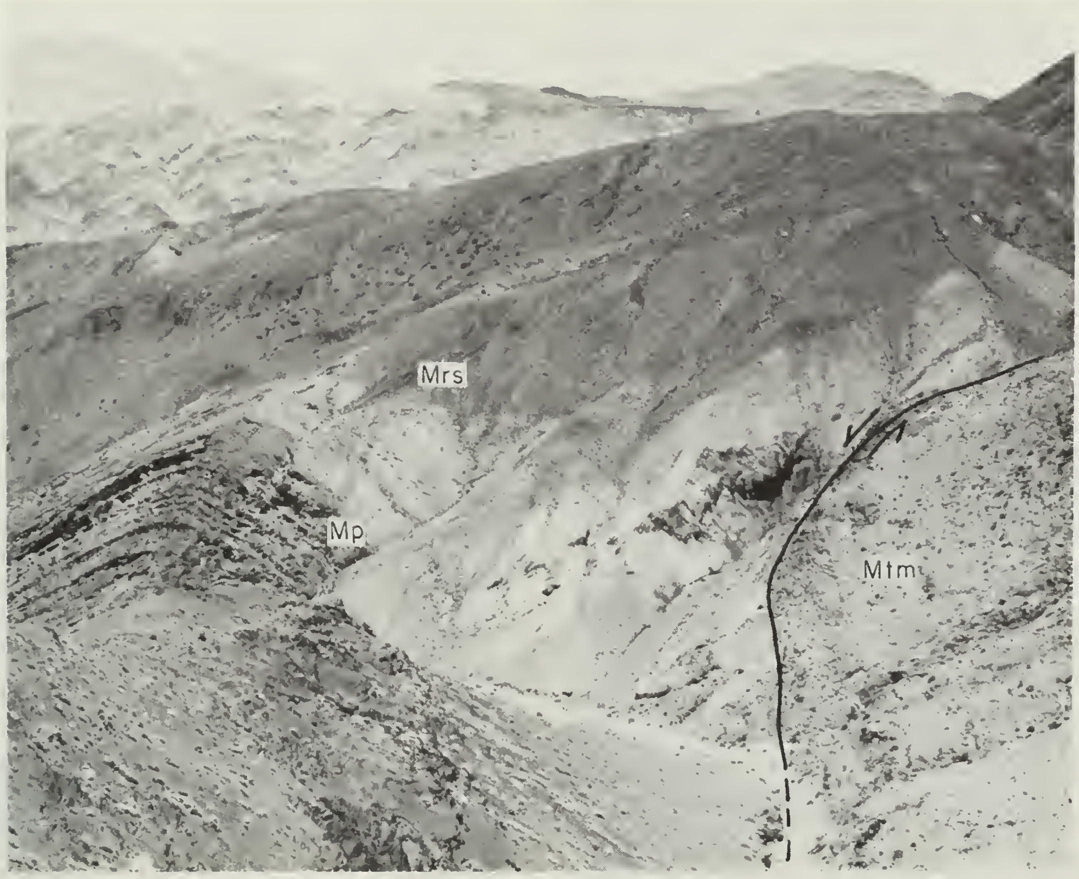


Figure 8. This anticline of the upper Perdido Formation (Mp) and the Rest Spring Shale (Mrs) is one of the few places in the quadrangle where the two formations make a normal contact. The Saline and Inyo Ranges rise in the background. (Mtm = Tin Mountain Limestone.)

The lithology of the Perdido Formation is variable ut generally consists of 600 to 700 feet of sandy mestone, calcareous sandstone, conglomerate and, ›cally, chert. In the southern part of the quadrangle, pproximately 20 feet of black calcareous argillite verlies the Tin Mountain Limestone, followed by a)- to 15-foot bed of dark gray limestone. The limeone is lenticular and is not found toward the north, here white- and pink-weathering platy siltstone overes the Tin Mountain Limestone. The bulk of the ›rmation is best exposed in the central part of the ea and consists of gray medium-bedded quartzitic nestone, and calcareous sandstone that weathers redown. The amount of sand appears to increase toard the northwest, although a few beds of chert ebble conglomerate are present in the southern part the quadrangle. Chert layers are present in the sal Perdido Formation in the south but are rare rther north. The contact with the overlying Rest ›ring Shale is either a fault or shows some moveent. Where the contact can be seen, a few feet of nk-weathering shale overlies sandy limestone of the rdido (fig. 8). The pink shale is overlain by oliveeathering shaly siltstones of the Rest Spring Shale.

McAllister (1952) collected Late Mississippian hester) fossils from the upper beds of the Perdido the Quartz Spring area, and possible earlier Mississippian (Kinderhook or Osage) fossils are present in the southern part of the Ubehebe Peak quadrangle (McAllister, 1956). Recently, Gordon (1964) has described in detail the cephalopods from these localities.

Rest Spring Shale

Shaly rocks overlying the Perdido Formation were termed Rest Spring Shale by McAllister (1952) and are typically exposed at Rest Spring five miles east of Teakettle Junction. The upper and lower contacts commonly show evidence of movement, so their precise nature is not known. The shaly rocks of the Rest Spring are overlain by medium to thick beds of gray limestone of the Keeler Canyon Formation and underlain by calcareous sandstone of the Perdido.

Olive-weathering shale and shaly siltstone are the dominant rock types. Occasional beds of brown-weathering sandy siltstone or fine-grained sandstone are present locally in the formation. Two or three thick beds of limestone are present in the upper 100 feet of the Rest Spring Shale in the southwestern part of the quadrangle. The basal part of the Rest Spring commonly contains concretions shaped like oblate spheroids. Much of the Rest Spring in the thrust slice on the west side of the Last Chance Range has been metamorphosed to an andalusite hornfels.

The thickness of the Rest Spring Shale is uncertain because of faults, cleavage and folds developed in the shale. Less than 300 feet of Rest Spring is present three miles west of Teakettle Junction, and more than 1500 feet is present four miles to the north, but the strata there are repeated by numerous small folds. In the southwest part of the quadrangle more than 750 feet of Rest Spring is exposed in a simple anticline. Here the formation is probably between 750 and 900 feet thick.

The age of the Rest Spring Shale is much debated. McAllister (1952 and 1956) regarded the Rest Spring Shale as Pennsylvanian (?), because it lies above rocks containing Late Mississippian fossils and beneath rocks containing moderately early Pennsylvanian fossils. Merriam (1963a), on the other hand, considered rocks of similar lithology at Cerro Gordo (upper Chainman Shale) to be Late Mississippian but left the possibility open that the upper unfossiliferous part may be Early Pennsylvanian. Recently, Gordon (1964) has described Late Mississippian cephalopods from the lower part of the type Rest Spring Shale. The age of the upper part remains uncertain.

Keeler Canyon Formation

The name Keeler Canyon Formation was first used by Merriam and Hall (1957, p. 4–7) for exposures in Keeler Canyon in the southern Inyo Mountains. Merriam and Hall defined the formation as embracing all the rocks above the equivalent of the Rest Spring Shale and below an unconformity at the base of the overlying Owens Valley Formation. No unconformity was observed in the Pennsylvanian and Permian rocks in the Dry Mountain quadrangle; thus the equivalence of the Keeler Canyon Formation to that of the type section is not certain.

The Keeler Canyon Formation along the southern boundary of the quadrangle consists of approximately 3900 feet of silty and sandy gray limestone that commonly weathers orange in the more impure parts. Platy and shaly orange-weathering calcareous siltstone forms interbeds between the medium- to thick-bedded limestone. Occasional beds of pink and purple weathering calcareous shale are also present. The limestone beds are commonly well laminated and show contorted bedding interpreted as penecontemporaneous slump structure. Many of the limestone beds are conglomeratic, with plates of limestone, up to six inches long and often forming an edgewise conglomerate, and pebbles of chert. Rarely, the bedding surfaces show evidence of scour and probably represent minor breaks in sedimentation (diastems).

The contact with the underlying Rest Spring Shale is commonly faulted, but, where it is unfaulted and clearly exposed, it appears to be gradational. The upper beds of green shale in the Rest Spring Shale weather pale purple and contain thin beds of gray limestone, which becomes more common upward. Shale of the Rest Spring Shale gives way to silty limestone interbedded with medium- to thick-bedded gray limestone in the Keeler Canyon Formation. Several thin beds of chert pebble conglomerate are usually present in the lower 20 feet of the Keeler Canyon.

McAllister (1956) thought the rocks mapped in t Dry Mountain quadrangle as the Keeler Canyon Fo mation were the lower limestone member of the Bi Spring (?) Formation. He collected fusulinids of po sible Middle Pennsylvanian age (Atokan or early D Moines) in the Quartz Spring area (McAllister, 195 from rocks lithologically equivalent to the base of t Keeler Canyon Formation, which he called Tihvipa Limestone. Merriam and Hall (1957) likewise co lected possible Atokan fossils at the base of the ty section of the Keeler Canyon. From a slightly high stratigraphic position, McAllister (1956) collected po sible Early Permian fossils in the Ubehebe Peak qua rangle. Both McAllister (1956) and Merriam and H (1957) collected Early Permian (Wolfcamp) foss from the upper part of sections probably equivale to the Keeler Canyon Formation of this report. B cause there is no apparent unconformity in the Pen sylvanian-Permian rocks, it is not certain that t Keeler Canyon Formation of the Dry Mountain qua rangle is the stratigraphic equivalent of the type se tion, but the fossils seem to suggest that it is.

Owens Valley Formation

Merriam and Hall (1957) defined the Owens Vall Formation using strata exposed along the west side the southern Inyo Mountains. Because the unconfor ity at the base of the Owens Valley Formation in t type section is not present in the Dry Mountain qua rangle, correlation between the rocks of the two are is uncertain.

The Owens Valley Formation consists of gray sha calcareous siltstone and shale, with interbedded re weathering calcareous sandstone and thin- to thic bedded limestone (see fig. 14, p. 18). Only ab 600 feet of the Owens Valley Formation is expos usually in structurally complex areas, so the to thickness and lithologic character of the formation unknown. Rocks of the Owens Valley Formation metamorphosed to hornfels and marble for varyi distances from intrusive contacts in the southern p t of the quadrangle.

The type Owens Valley Formation ranges in a from ". . . late Wolfcamp or early Leonard to Wo and possibly Guadalupe age" (Merriam and Hall, 19 p. 11). McAllister (1956) mapped similar Perm shaly rocks in the quadrangle area as the shale mem of the Bird Spring (?) Formation.

CENOZOIC ROCKS

Volcanic Rocks of the Saline Range

Two volcanic rock units were distinguished in e Saline Range; however they are partly lateral equi lents and are not always easily separated. Beneath e basalt along the east side of the Saline Range and a few places in the Last Change Range is a seque e of reworked volcanic rocks and sediments mapped s reworked pyroclastic and volcanic rocks (QT . Water-lain pumiceous material is characteristic of t s unit, although the unit may contain sand or gra beds and sometimes basalt flows. In the main part of the Saline Range a sequence of mainly felsic volcanic rocks crops out (QTv). Rhyolitic pyroclastic rocks ranging from red welded tuff to white-weathering pumiceous tuff are common. These rocks may be interbedded with small amounts of reworked volcanic and basaltic debris. Like the water-lain pumiceous unit (QTp), these rocks underlie the most recent basalt lows, which are mapped as a separate unit.

Older Alluvial Deposits

Throughout the main part of the southern Last hance Range are numerous deposits of poorly sorted onglomerate that generally lie at low elevations, but ome deposits are along the crest of the main ridge everal thousand feet above the present alluvial basins. he age relations between the different alluvial de- osits is unknown. Most of the older alluvium is prob- bly pre-basalt in age and is mapped as older fan- lomerate (QTf), but, where the basalt does not irectly overlie the alluvium, the pre-basalt age cannot e proven and the rocks are mapped as older alluvium Qog). A least some of the older alluvium at low ele- ations along the central and northeast side of the ast Chance Range is post-basalt, since the upper part f the sequence contains boulders of basalt.

Nearly all of the older alluvial deposits are poorly rted, composed of boulders, cobbles and pebbles of ck types adjacent to the deposit. The matrix is fine- rained material of the same range of composition as e clasts. Most of the sedimentary material has been econdarily cemented by calcite, usually in the form caliche.

Many of the deposits contain exotic boulders whose urce is unknown. Several examples of older alluvium at contains exotic boulders worth noting are:

1) Three small patches of older alluvium (Qog) ar the northern crest of the range contain rounded angular exotic boulders up to three feet in diameter. hese are syenite, Lower Cambrian (?) quartzite, and mbrian mottled limestone and dolomite. The nearest eality from which to derive the Cambrian rocks is ur to five miles to the north, in the Last Chance nge. The source for the syenite is unknown.

2) The older alluvium (Qog) in the large reentrant lley at the east side of the Last Chance Range, three les north of Dry Mountain, contains thick beds of ffaceous sandstone and conglomerate made of pu- ceous material. Much of it is reworked and cross- dded. The tuffaceous material is similar to that pped as QTp in the Saline Range to the west, across present Last Chance Range drainage divide.

3) A small area covered by older alluvium (Qog) miles north-northwest of Dry Mountain contains nded boulders of Eureka (?) Quartzite up to three t in diameter. A small outcrop of Eureka (?) is se by; however, these are the only boulders present the ridge top and the rounded nature of the boul- s suggests a more distant source.

A similar type of deposit is found on the Lost Burro mation one mile north of the southern boundary of the quadrangle. The basal beds of the older alluvium (Qog) contain rounded boulders of Eureka Quartzite and reddish, possibly Lower Cambrian, quartzite up to six feet in diameter (fig. 9). A few boulders of a peculiar orbicular granodiorite are also present. These basal beds are overlain by more normal older alluvium containing cobbles of all Paleozoic rock types. Some tuffaceous rocks are present in the upper part of this older alluvium. The source for the Eureka Quartzite boulders could be an area 1½ miles southeast along the west side of Racetrack Valley. The source for the Cambrian quartzite is unknown.

4) The remaining deposits of older alluvium reflect local sources. For example, the older fanglomerate (QTf) underlying the basalt in the southwest part of the quadrangle and resting on granite and quartz monzonite contains rounded cobbles up to two feet in diameter identical to the igneous stocks that underlie these deposits.

Basalt

Basalt covers large areas in the Saline Range, the southwestern part of the Last Chance Range, and small areas in the central Last Chance Range. The basalt is only the eastern fringe of an extensive basalt field in the main part of the Saline Range west of the Dry Mountain quardangle. A few thin sections of the basalt were studied and all showed similar composition and texture. Phenocrysts of olivine and plagioclase make up about 10–15 percent of the rock; they are set in a groundmass composed of plagioclase needles, olivine and pyroxene. The rims of the olivine crystals are altered to iddingsite.

Some exposures of basalt show an internal ropy structure which can be used to determine the direction of flow. This was particularly useful in the long basalt tongue near the north end of the quadrangle.

The inferred flow direction is west to east, and the east edge of the main part of the flow ends at the crest of the range. This direction suggests the source area was the main basalt field to the west, in the Saline Range, and indicates that the main elevation of the Last Change Range is post-basalt. Several small basalt plugs and one dike are present one mile south of the flow, but the flow direction is not consistent with the suggestion that the intrusions were the source. A possible alternative source exists in the area of the small basalt outcrops ½ mile to the west, but no evidence of a vent was uncovered there.

Landslide Deposit

Along the east side of the Dry Mountain quadrangle a deposit of megabreccia overlies rocks that are Cambrian through Silurian in age. The megabreccia contains angular fragments, up to eight feet in diameter, of rocks that are mostly Devonian. One to two miles east of the quadrangle, in the west slope of the Panamint Range, Devonian rocks crop out in four landslide scars; thus the megabreccia is certainly of landslide origin. This landslide has been named the Tin Mountain landslide and has been described by Burchfiel (1966).

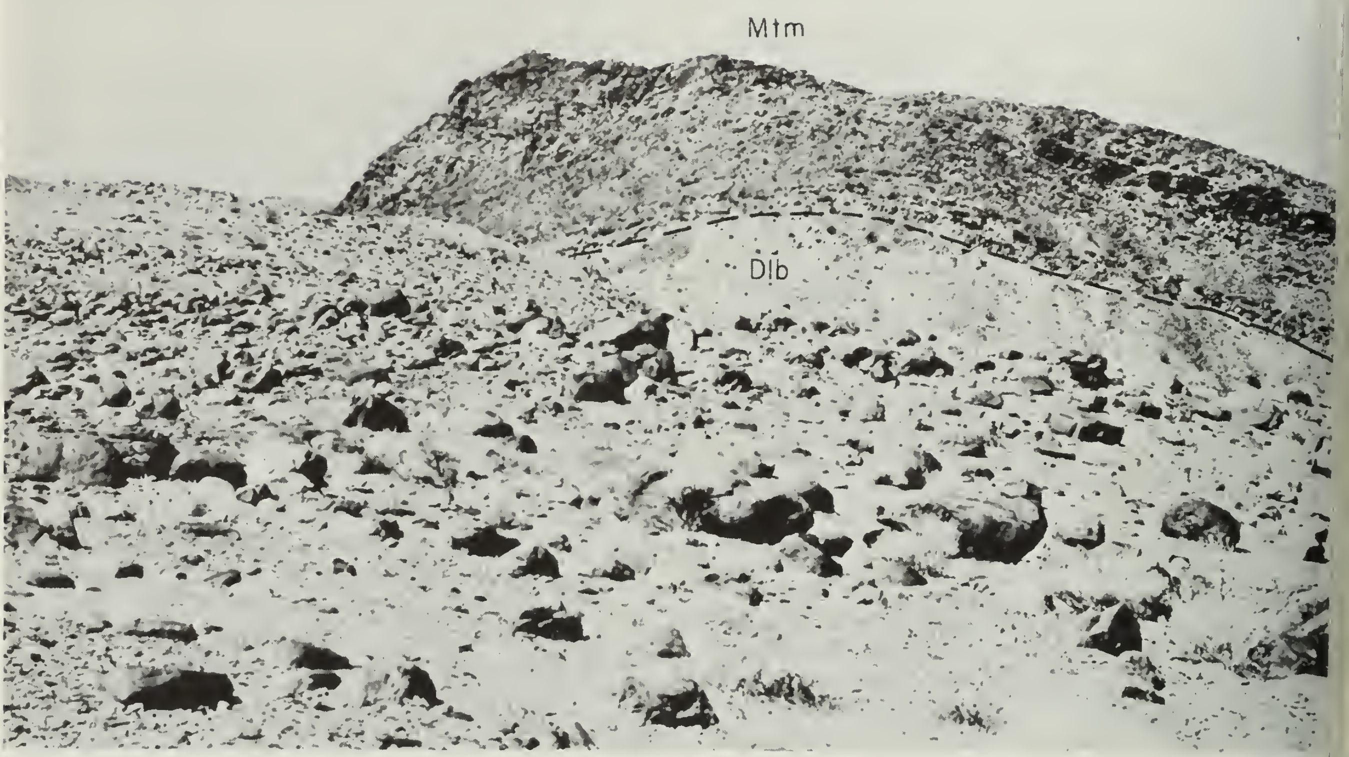


Figure 9. Basal boulder beds litter the older alluvium three miles west of Teakettle Junction. Most of these boulders are Eureka Quartzite, but some are exotic, composed of orbicular granodiorite and Cambrian (?) red quartzite. (Mtm = Tin Mountain Limestone, Dlb = Lost Bur Formation.)

Lake Deposits

In the southwest corner of the quadrangle thin-bedded siltstones cemented with evaporite material are part of the extensive Saline Valley deposits.

Spring Deposits

Adjacent to Upper Warm Spring, in sec. 9, T. 13 S., R. 39 E., M.D.M., calcareous deposits form a distinct white weathering ledge. The material is calcium carbonate and undoubtedly numerous other salts. The composition of the rock was not studied.

Talus Deposits

Talus of angular debris of adjacent rock is mapped in only a few places where the deposits are large or cover important geologic contacts.

INTRUSIVE IGNEOUS ROCKS

Three large bodies of intrusive igneous rock are present in the Dry Mountain quadrangle: (1) a granitic stock that crops out over about 14 square miles in the southwest corner of the quadrangle; (2) a smaller stock that forms hill 6196 at the west side of Round Valley; and (3) a small stock 1½ miles west of Teakettle Junction. Three small granitic bodies crop out near the southern boundary of the quadrangle. All the granitic stocks are regarded as part of the Hunter Mountain Quartz Monzonite of McAllister (1956).
Numerous dikes are present in the southern part
the quadrangle and a few are present farther nort
The dikes have been designated as either silicic
mafic. In order to compare the igneous rock typ
present in the Dry Mountain quadrangle with those
adjacent areas, the classification scheme in McAlliste
work (1956) is used.

Hunter Mountain Quartz Monzonite

All the intrusive igneous stocks in the Dry Mounta
quadrangle are similar in composition to rocks th
crop out extensively in the Ubehebe quadrangle to t
south and make up the Hunter Mountain Quartz Mo
zonite. Only the rocks at hill 6196 and the two sm
outcrops three miles to the east have compositio
similar to the main body of the Hunter Mounta
Quartz Monzonite. All the other intrusive rocks a
similar to border phases of the quartz monzonite.

The large stock in the southwest corner of the qua
rangle consists of medium- to coarse-grained qua
monzonite. Some of the pinkish potassium feldsp
crystals are nearly one inch long; most are less th
¼ inch long. One thin section was studied from
specimen collected from sec. 11, T. 13 S., R. 39
M.D.M. The rock contains approximately 55 perce
potassium feldspar and 30 percent sodic plagiocla
Both feldspars are saussuritized with the more cal
(?) centers of the zoned plagioclase most strong
altered. Commonly the larger potassium feldspar gra

poikilitically enclose plagioclase and other potassium feldspar grains. Quartz is interstitial and makes up about 10 percent of the rock, so the rock is quartz monzonite, although very nearly a true granite. Green hornblende makes up about five percent of the rock and is the only dark mineral present in noticeable amounts.

A sample from the stock at hill 6196 that contained both a coarse-grained and fine-grained phase was studied in thin section. Both phases contained approximately 45 percent potassium feldspar and 30 percent odic plagioclase. Both feldspars are altered, with the calcic centers of the plagioclase most strongly altered. Commonly large crystals of potassium feldspar poikilitically enclose grains of zoned plagioclase. Quartz is interstitial and forms five to seven percent of the ock, so it is a monzonite. The coarse-grained phase contains 15 percent green hornblende whereas the fine-grained phase contains about 20 percent.

Three miles east of hill 6196 two small outcrops of quartz monzonite are similar in compositon to the rock at hill 6196. The rock differs in that it contains a trace of biotite rather than hornblende and five to 0 percent more quartz. All the feldspars are strongly tered to clay minerals, making the determination of omposition difficult.

The stock 1½ miles west of Teakettle Junction conins numerous coarse- and fine-grained phases. Some ocks contain pink potassium feldspar crystals up to hree inches long. Four thin sections of the different hases were examined. All of the coarse-grained phases e potash syenites, but the mineralogy is variable. uartz is usually rare or absent and the dark minerals e green biotite, aegirine-augite or a green sodic (?) ornblende. Magnetite and sphene occur as accessory inerals. The fine-grained phases are potash granite, arly devoid of plagioclase. Green sodic (?) hornende is also present, along with rare feldspathoids.

Dikes and Sills

Two types of mafic dikes are present in the quadngle. Two miles north of Dry Mountain are several kes and four circular plugs of olivine basalt. In sec. T. 14 S., R. 39 E., M.D.M., a dark green dike that ts the basalt consists of calcic plagioclase and green rnblende with minor amounts of quartz, potassium ldspar and brown biotite. The rock is a granodiorite d is probably related to the extrusion of the basalt cause it certainly was emplaced much later than the nitic stocks nearby.

Nearly all the silicic dikes and sills are a few feet ck, fine grained and strongly altered. Composition- they are granite and quartz monzonite and are bably related to the nearby granitic stocks. Near east-central boundary of the quadrangle a dark en dike cuts the Carrara Formation and Zabriskie artzite. In thin section the rock was determined to hornblende quartz monzonite. The hornblende and lspars are strongly altered to epidote and zoisite. e age of this dike is unknown.

STRUCTURE

The structure of the Dry Mountain quadrangle can best be discussed by describing the structure in each of the three ranges: Panamint, Last Chance and Saline.

Panamint Range

A segment of the Racetrack thrust is exposed along the part of the west flank of the Panamint Range that lies within the Dry Mountain quadrangle. It thrusts rocks of the Pogonip Group eastward over Devonian and Mississippian rocks. The rocks underlying the thrust are themselves imbricated by thrust faults of smaller magnitude. McAllister (1952) recognized the Racetrack thrust and later (1956) demonstrated that it could be followed for more than 10 miles farther south. The northerly extension of the Racetrack thrust is in doubt, but, if the Cambrian and Ordovician rocks in the eastern Last Chance Range are in the upper plate of the thrust, then the Racetrack thrust can be extended at least eight miles farther north.

Last Chance Range

A large fault, which places Cambrian and Ordovician rocks to the east against Ordovician through Devonian rocks to the west, can be followed south along the east side of the Last Chance Range, from a point 3 miles east of Dry Mountain almost to the border of the quadrangle. The dip of the fault is generally steep and, where the fault surface can be seen, it dips 60 degrees to the east. The direction of dip suggests the fault is a reverse fault, east side up 2,500 to 7,300 feet, depending on where the stratigraphic separation is measured.

The older rocks east of the fault are in contact with younger rocks to the west. The older rocks, although structurally high, are topographically low, lying between the high parts of the Last Chance and Panamint Ranges. Assuming that faulting has controlled topography, the movement of the west side of the older rocks is normal, east side down. However, if the fault is a normal fault, east side down, then possibly these Cambrian-Ordovician rocks are part of the upper plate of the Racetrack thrust and have been faulted down from a structural position higher than the younger rocks west of the fault. From relationships in the southern Ubehebe quadrangle, this latter interpretation does not appear likely.

The structure in the northern part of the Last Chance Range within the Dry Mountain quadrangle is half of a large dome. The rocks dip away from a central area in the large reentrant valley three miles north-northeast of Dry Mountain (fig. 5). In some areas the rocks do not follow this general structural configuration, but the exceptions can be explained by changes in dip due to faulting (pl. 1, section F-F′). West of the dome the dip becomes less steep westward until the rocks become horizontal and in some places dip gently eastward to form an open syncline (pl. 1, section F-F′). The belt of horizontal strata can be generally followed south along the west flank of the Last Chance Range as a broad structural bench before

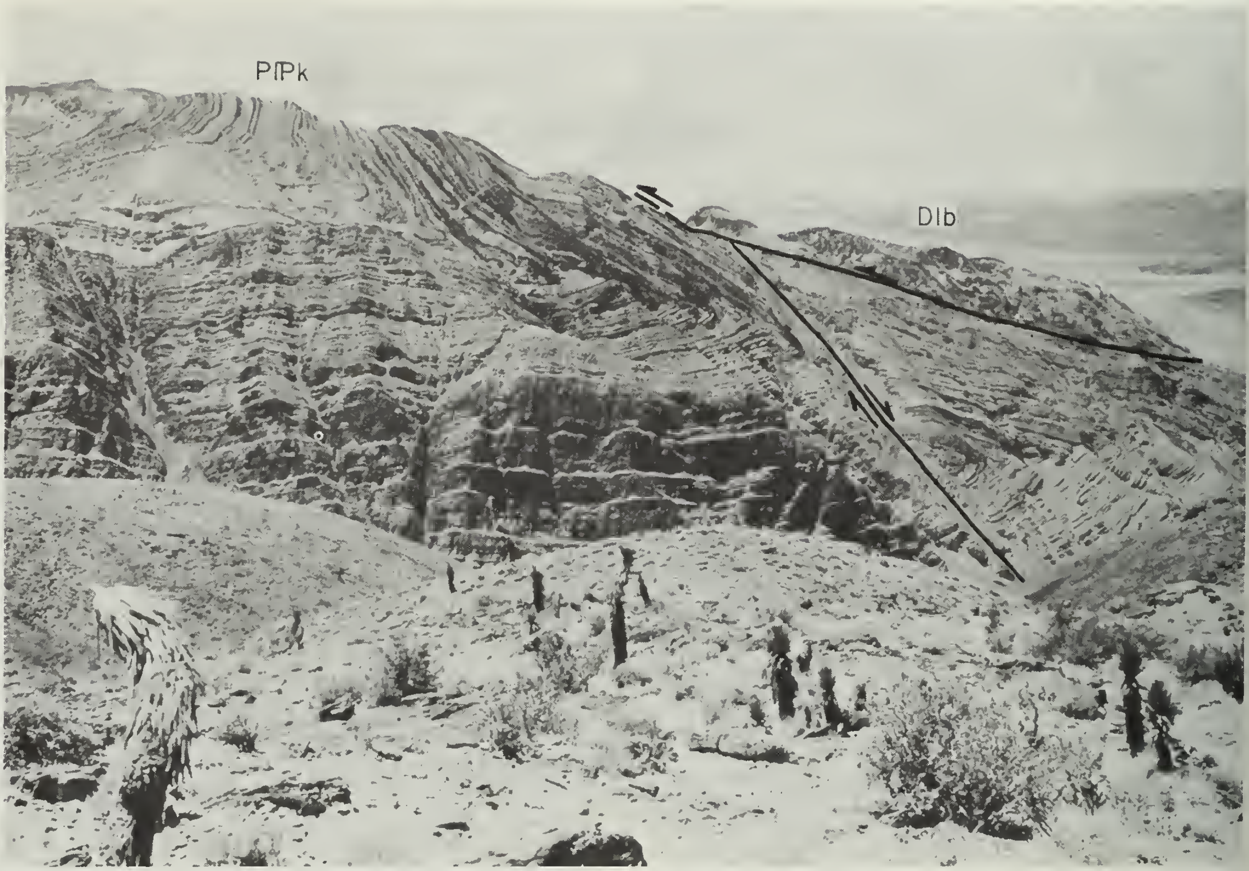


Figure 10. Rocks of the Keeler Canyon Formation (PIPK) turn over into a disharmonic recumbent syncline, in this southward view at the west side of the Last Chance Range. The overturned limb is overthrust by the Lost Burro Formation (Dlb).

the rocks then dip again to the south or southeast (pl. 1, section E-E′). The dip steepens to as much as 50 degrees in places, with the axis of the flexure bearing approximately N. 30 W. through the outcrops of Mississippian rocks (pl. 1, section E-E′). The axis of the flexure trends into the alluvium of upper Saline Valley to the west and Round Valley to the east and cannot be recognized elsewhere.

Northwest of Round Valley the Pennsylvanian and Permian rocks of the Keeler Canyon and Owens Valley Formations turn over into a large recumbent syncline with a south-bearing axis that plunges five degrees to the south (fig. 10). The syncline is strongly disharmonic, changing from an upright syncline to a recumbent syncline within one mile (pl. 1, section D-D′). The syncline can be followed to the south for two miles before it passes beneath younger basalts. Overturned beds of the Owens Valley Formation present farther south probably represent the overturned limb of the fold as it strikes into the quartz monzonite of hill 6196. A thrust plate of rocks belonging to the upper part of the Lost Burro Formation lies on the overturned limb of the fold (pl. 1, section D-D′ and fig. 10). Another thrust, perhaps of small magnitude, places Rest Spring Shale, metamorphosed to andalusite hornfels, on the thrust plate of the Lost Burro Formation along its northern edge and on the Rest Spring Shale and Keeler Canyon Formation of the reversed limb of the recumbent fold along its eastern edge (l. 1, section C-C′).

Farther south in sec. 12, T. 13 S., R. 39 E., M.D.M., granite has intruded and metamorphosed the Paleoz c rocks. The marble and quartzite are Ordovic n through Silurian in age, representing the Pogo p Group, Eureka Quartzite, Ely Springs Dolomite, H l-den Valley Dolomite and Lost Burro Formation. Th e rocks dip 20 to 30 degrees east and are structur y discordant with respect to the Mississippian and Pe n-sylvanian rocks to the north and east, which gener y dip steeply west. The contact between the two r k masses is a flat thrust fault clearly exposed 0.2 r le east of sec. 12, T. 13 S., R. 39 E., M.D.M. The Or o-vician and Silurian rocks may be part of the th st plate seen in the Saline Range to the west (pl. 1, s c-tion E-E′).

Near the east side of Round Valley the Lost Bu o Formation strikes north and is exposed continuou y to the southern boundary of the quadrangle. No n-west of Round Valley the Lost Burro shows v y strong disharmonic folding which dies out toward e south (figs. 11 and 12). The structure west of the o t-crops of the Lost Burro Formation at the south n boundary of the quadrangle is quite different f m that just described near Round Valley. The struct re here is one of alternating north-trending anticl es and synclines (pl. 1, section A-A′) rather than e

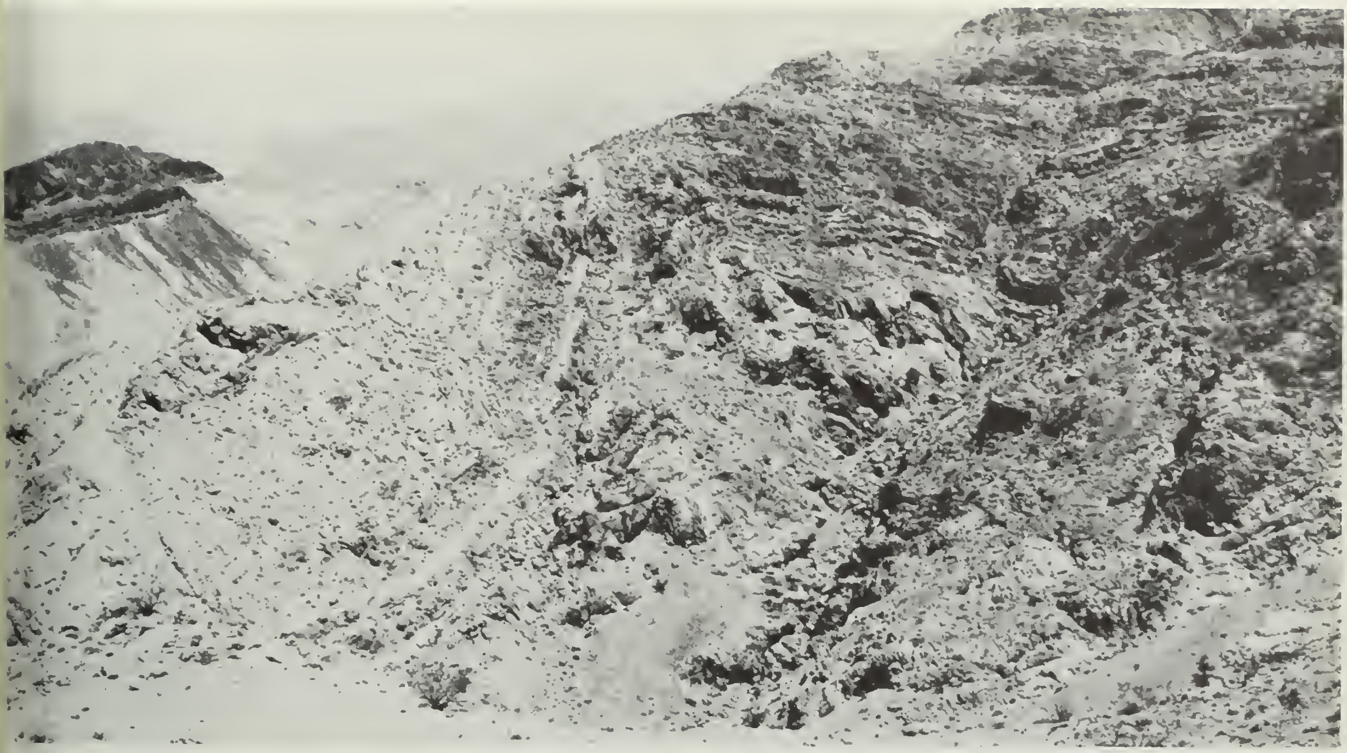
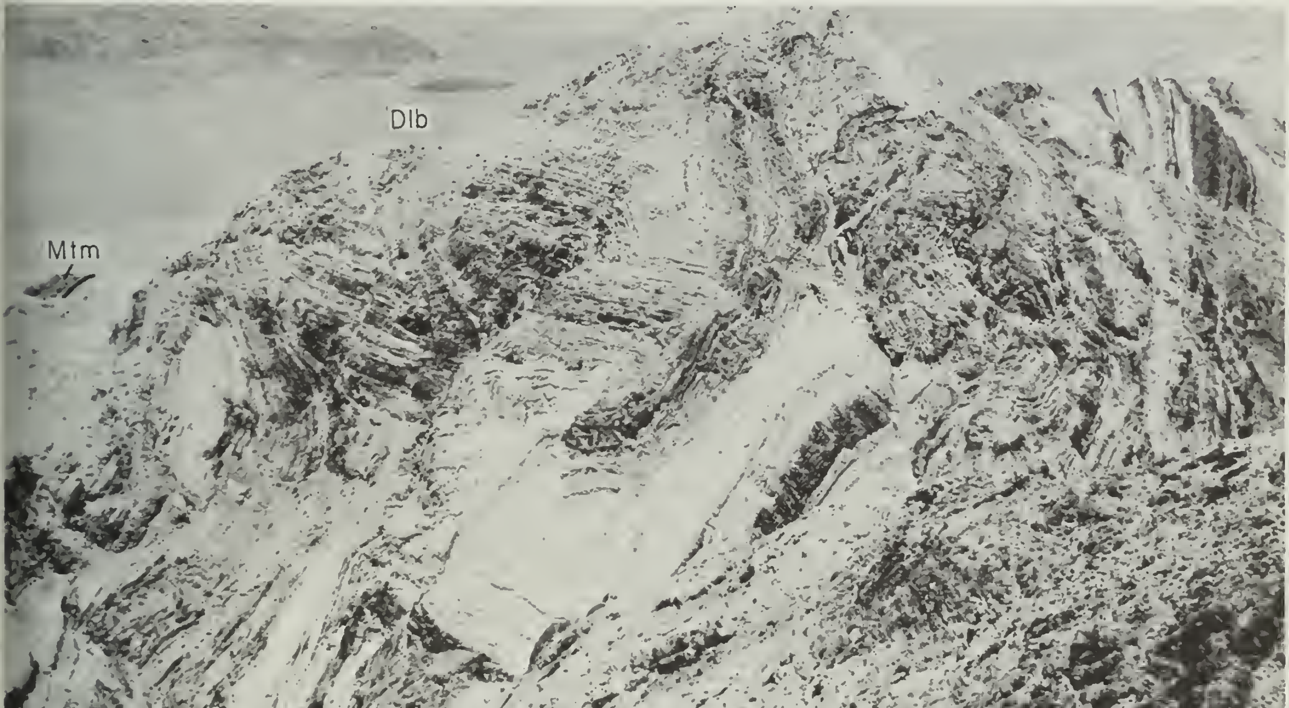


Figure 11 (above). Disharmonic folds appear in upper Lost Burro ormation near Round Valley. The complexity of the folds increases orthward and culminates in the structure shown in Figure 12.

Figure 12 (below). Highly deformed Lost Burro Formation (Dlb) appears three miles west of Teakettle Junction. The structures are disharmonic: overlying Tin Mountain Limestone (Mtm) is unfolded.



large recumbent syncline. The folds are offset 0.4 mile by a northeast-striking left-lateral strike-slip fault. The relationship between these folds and the large recumbent fold to the north is not known because of alluvial and basalt cover and distortion of the structure near the southern margin ofthe quartz monzonite stock at hill 6196. Also, in sec. 1, T. 14 S., R. 39 E., M.D.M., a thrust fault that dips approximately 45 degrees south thrusts Rest Spring Shale and lower Keeler Canyon Formation north over the Keeler Canyon and Owens Valley Formations. The folds in the hanging wall are not found in the footwall. This fact suggests that, if the thrust continues eastward under the basalt, it may not be possible to match structure north and south of the thrust.

Relations between the intrusive rocks and the Paleozoic rocks are quite variable. In places the contact is faulted. In sec. 36, T. 13 S., R. 39 E., M.D.M., a small wedge of quartz monzonite is thrust eastward over the Keeler Canyon Formation (fig. 13). Also, the Rest Spring Shale that contacts a small body of granite south of the strike-slip fault near the southern boundary of the quadrangle (pl. 1, section A-A′) does not show significant contact metamorphism adjacent to the granite. The contact is nearly horizontal and appears to be faulted. Both examples given above suggest some lateral compression followed intrusion.

Around the quartz monzonite stock of hill 6196 the contact relations are variable. Along the north side, beds of the Owens Valley Formation are discordant and are crumpled for about 100 yards from the contact, while on the west side, the contact is concordant with marble of the Owens Valley Formation (fig. 14 and pl. 1, section B-B′). Along the south side of the quartz monzonite stock, the Keeler Canyon Formation is partly discordant and partly concordant where the beds strike parallel to the contact. Near hill 5064 the most widespread contact metamorphism is present. Here, small sills and dikes of quartz monzonite intrude the marble of the Keeler Canyon, and skarns of wollastonite and garnet are present.

Three outcrops in the southern Last Chance Range are curious. At the north end of Round Valley are two outcrops of Eureka Quartzite breccia resting on Rest Spring Shale and Perdido Formation. The larger of the two areas covered by Eureka contains some large brecciated blocks that are probably Ely Springs Dolomite. The breccia rests on a surface dipping about 20 degrees south. All the quartzite in these outcrops is brecciated, and bedding is not visible except within the blocks. Two interpretations are possible: the breccia is the basal part of the thrust plate or it is part of a landslide mass. If the breccia is considered the upper plate of a thrust, it might represent klippen of the thrust present four miles farther west that involves Ordovician rocks. If the breccia is considered a landslide, the closest possible source for the Eureka Quartzite would have been a mass that once overlay the Antelope Valley Limestone one to two miles to the east but has been removed by erosion. The present topography, however, would not allow a block to slide from east to west, because a high ridge of Lost Burro Formation now rises between the two areas.

The third curious outcrop consists of quartzi approximately 200 feet thick and brecciated at t base, that overlies the upper part of the Lost Bur Formation one mile east of sec. 30, T. 11 S., R. 40 M.D.M. (fig. 15). The rock looks like Eureka Quart ite; if it is, it probably represents the upper plate a thrust. The quartzite may possibly be a great thickened equivalent of the upper quartzite unit the Lost Burro Formation, but generally that unit no more than 10 to 15 feet thick, commonly less th eight feet. It is possible that the outcrops are remne of an extensive southern Last Chance Range. The o crops are so small and widely spaced that a defin answer is not possible.

Saline Range

The Saline Range contains an important thru fault visible only at two places in the Dry Mount quadrangle where Lower Cambrian rocks rest Mississippian rocks. At the western margin of t quadrangle the thrust dips east and all the Cambri rocks in the Saline Range are part of the upper pl of the thrust. Most of the Cambrian rocks dip 45 70 degrees east except along the east side of the S line Range, where a large north-trending fault brin up west-dipping Lower Cambrian rocks of the Ca rara Formation. In one small valley, the Carrara F mation is clearly seen to overlie the Mississippian R Spring Shale along a gently westward-dipping thru fault (pl. 1, section E-E′). Here, rocks at the base the thrust are several hundred feet above the base the Carrara Formation, an indication that the thr cuts upward in the section from west to east. The e tent of this thrust is uncertain, but the Ordovici rocks in sec. 12, T. 13 S., R. 39 E., M.D.M., are he considered part of the upper plate. With less certain the three outcrops of Eureka Quartzite discussed abo may also be part of the upper plate. The large ov turned fold along the west side of the Last Chan Range and numerous smaller folds in the Saline Ran suggest the thrust moved east or slightly north of ea.

Most of the Saline Range consists of volcanic a alluvial rocks which dip gently east and unconfor ably cover the more steeply-dipping Paleozoic roc The volcanic rocks are cut by numerous north-nor east-trending normal faults. Several of these fau have their maximum dip-slip component near the ce ter of the fault trace; the dip-slip component nea disappears toward the ends of the fault trace.

Extent and Age of Thrusting

The two major thrust faults present in the D Mountain quadrangle can be traced for considera distance beyond the quadrangle boundaries. The Ra track thrust has been extended by McAllister (195 for at least 10 miles to the south. If the Cambrian a Ordovician rocks west and north of Teakettle Ju tion are part of the upper plate of the Racetra thrust, which seems quite likely, the thrust can extended at least eight miles farther north. In t Dry Mountain quadrangle, rocks regarded as part the upper plate of the Racetrack thrust are intrud

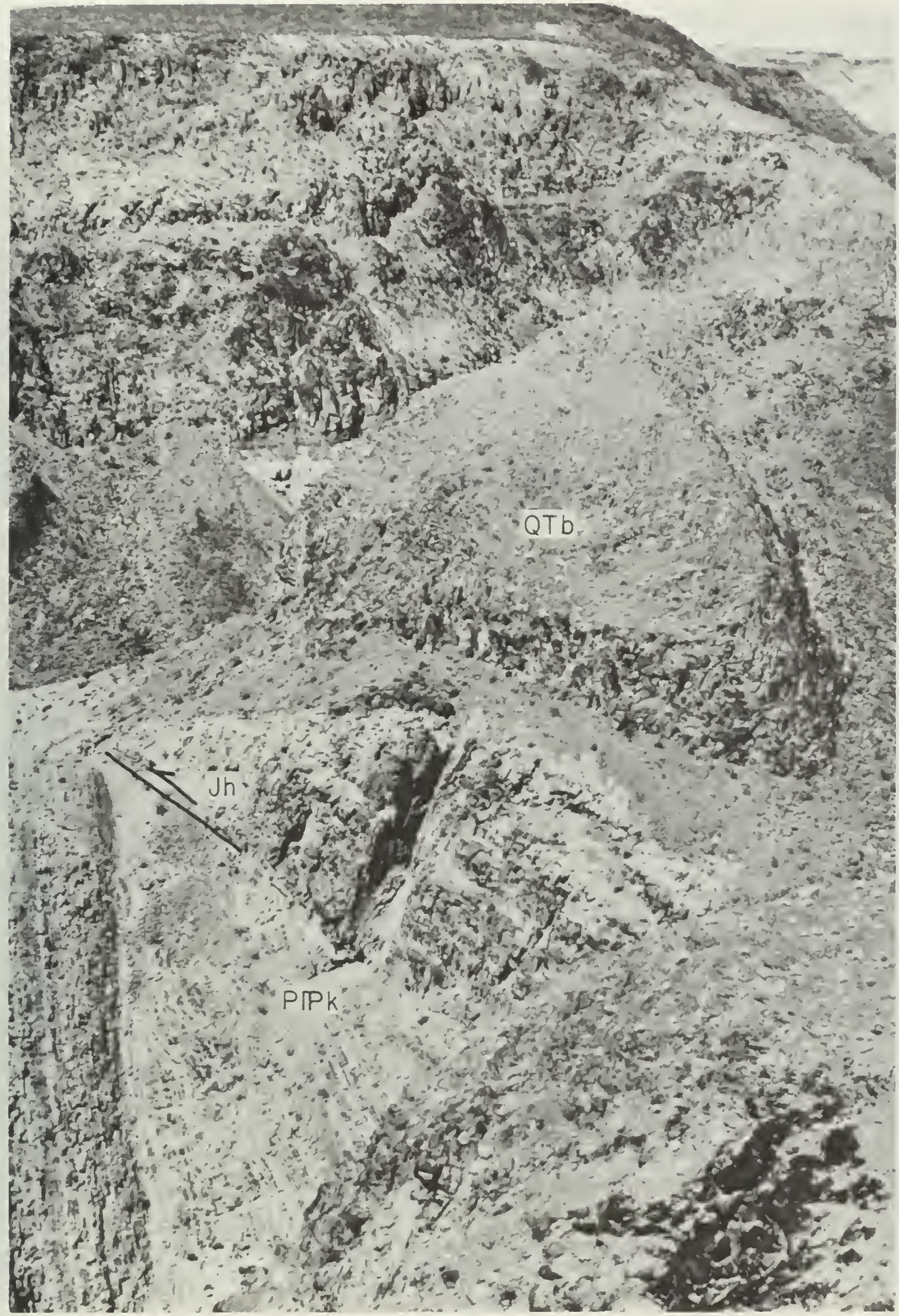


Figure 13. A wedge of Hunter Mountain Quartz Monzonite (Jh) thrusts over Keeler Canyon Formation (PIPK). Basalt (QTb) caps all the hills.

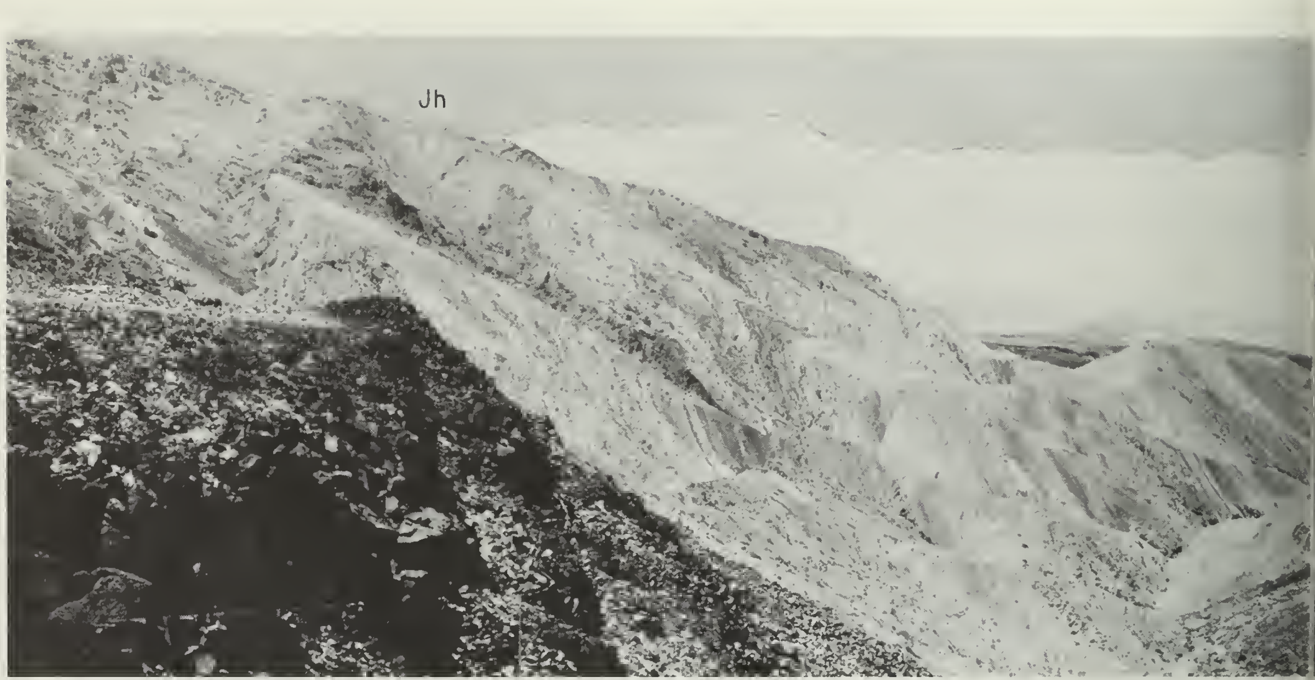


Figure 14. This view looks south at a contact between the overturned Owens Valley Formation and the quartz monzonite stack (Jh) at hill 61

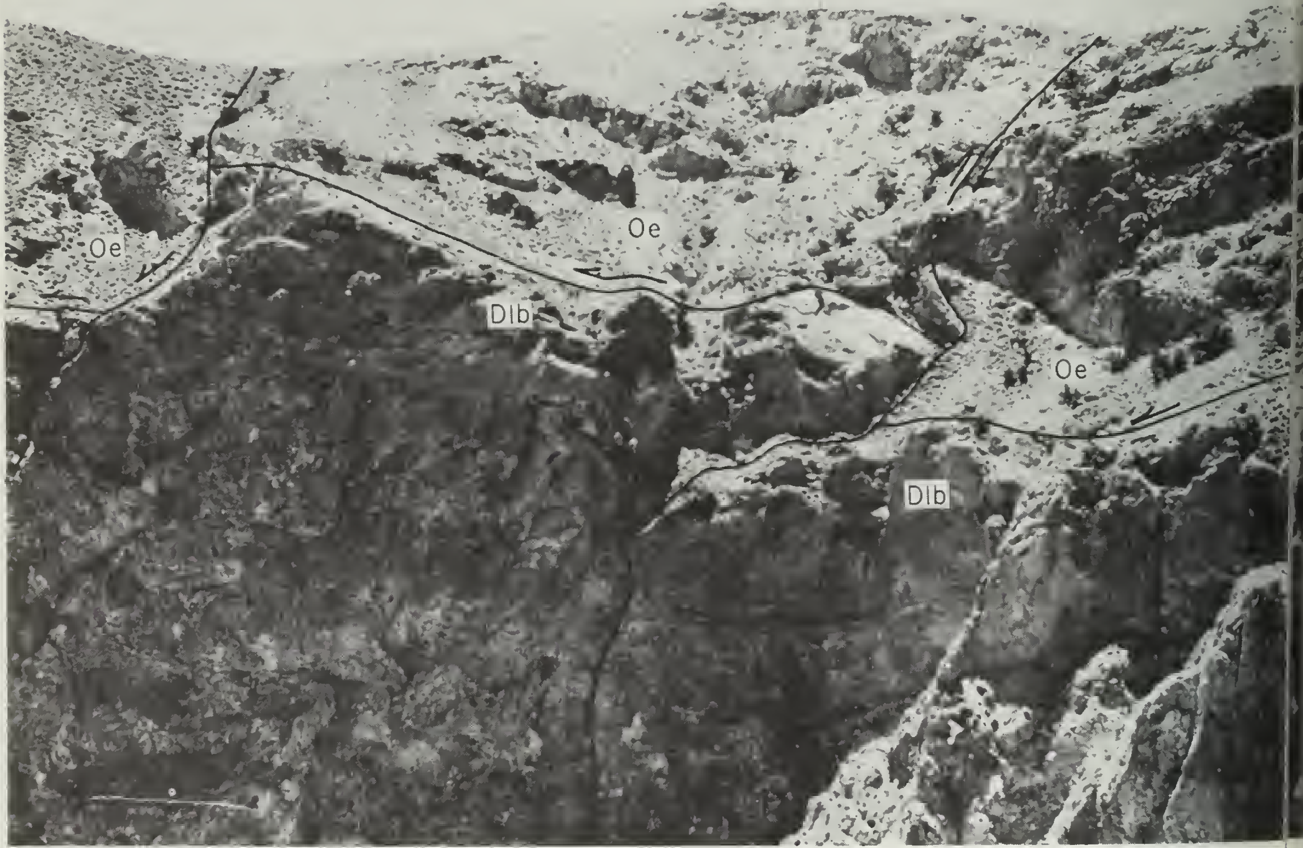


Figure 15. Eureka Quartzite (Oe) thrusts over the upper part of the Last Burro Formation (Dlb) a mile southeast of the marble bath at the th end of the quadrangle.

- syenitic outliers of the Hunter Mountain Quartz onzonite 1½ miles west of Teakettle Junction. Far-er south, in the Ubehebe Peak quadrangle, the rust is intruded by the main body of the Hunter ountain Quartz Monzonite. Thus, the movement of e thrust must be earlier than intrusion of the quartz onzonite.

The second, and certainly the most widespread, rust fault present in the Dry Mountain quadrangle the thrust exposed in the Saline Range and eastern rt of the Last Chance Range. This thrust has been ipped for several miles farther west into the Wau-ba Wash quadrangle (D. C. Ross and C. A. Nelson, rsonal communication, 1964) and 15 miles farther rth into the Last Chance quadrangle (J. H. Stewart d B. W. Troxel, personal communications, 1964); is, the thrust is of regional extent. If the Ordovician, urian and Devonian rocks in sec. 12, T. 13 S., R. 39 . M.D.M., are part of the upper plate of this thrust, they are intruded by the granite regarded as part of the Hunter Mountain Quartz Monzonite, and the age of the thrusting is preintrusion.

Both of the major thrust faults in the Dry Mountain quadrangle are cut by granitic rocks associated with the Hunter Mountain Quartz Monzonite. Biotite from a sample of quartz monzonite collected from sec. 16, T. 13 S., R. 39 E., M.D.M., was dated by the potassium argon method * at 152 m.y.b.p. A whole rock potassium-argon age of 139 m.y.b.p. was obtained from the syenite 2 miles west of Teakettle Junction. The intrusion of the syenite most likely belongs to the same event that emplaced the quartz monzonite, because the whole rock age is only a minimum. Thus the folding and thrusting in the Dry Mountain quadrangle is earlier than 152 m.y. (Late Jurassic) and later than Early Permian.

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* Dating was done in the Rice University Department of Geology laboratory.

REFERENCES

nes, Horley, and Christiansen, R. L., 1967. Cambrian and Precambrian rocks of the Graom District, Nevada Sauthern Great Basin, J.S.A.S. Bull. 1244G, 33 p.

nes, Harley, and Palmer, A. R., 1961, Revisian of stratigraphic iomenclature of Cambrian rocks, Nevada Test Site and vicinity, Nevada: U. S. Geol. Survey Prof. Paper 424-c, p. c100–c103.

chfiel, B. C., 1964, Precambrian and Paleozoic stratigrophy of pecter Range Quadrangle, Nye County, Nevada: Amer. Assoc. etrol. Geologists Bull., v. 48, p. 40–56.

chfiel, B. C., 1966, The Tin Mountoin landslide and the origin of negabreccia: Geol. Soc. Amer. Bull., v. 77, p. 95–100.

nwall, H. R., and Kleinhampl, F. J., 1961, Geology of the Bare Mountain quadrangle, Nevada: U. S. Geol. Survey Quad. Map GQ-157.

don, M., 1964, Cailfornia carboniferous cephalopads: U. S. Geol. urvey Prof. Paper 483-a, 27 p.

gue, Arnold, 1883, Abstract of report on the geology of the Eureka istrict: U. S. Geol. Survey 3d Ann. Rept., p. 237–272.

l, W. E., and MacKevett, E. M., Jr., 1962, Geology and ore deposits f the Darwin quadrangle, Inyo County, California: U. S. Geol. urvey Prof. Paper 368, 87 p.

l, W. E., and Stephens, H. G., 1962, Preliminary geologic map of ne Panamint Butte quadrangle, Inyo County, California: U. S. Geol. urvey Mineral Investigations Field Studies Map MF-251.

zard, J. C., 1933, Notes on the Cambrian rocks of the eastern Mohove Desert, with a paleontological report by C. H. Crickmay: niv. California, Dept. Geol. Sci. Bull., v. 23, p. 56–80.

zard, J. C., 1937, Paleozoic section in the Nopah and Resting prings Mountains, Inyo County, California: California Jour. Mines nd Geol., v. 33, no. 4, p. 273–339.

zord, J. C., and Mason, J. F., 1936, Middle Cambrian formations of ne Providence ond Marble Mountains, California: Geol. Soc. Amer. ull., v. 47, p. 229–240.

ze, L. F., 1951, Lower Ordovician detailed stratigraphic sections for estern Utah: Utoh Geol. Mineralog. Survey Bull. 39, 100 p.

t, C. B., and Mabey, D. R., 1966, Stratigraphy and structure, Death olley, California: U. S. Geol. Survey Prof. Paper 494-a, 162 p.

, Clarence, 1878, Systematic geology: U. S. Geol. Expl. 40th parall Rept., v. 1., 803 p.

, Edwin, 1933, The Eureka Quartzite of the Great Basin region: mer. Jour. Sci., 5th series, v. 26, no. 151, p. 27–44.

jenheim, R. L., Jr., and Tischler, Herbert, 1960, Mississippion ond evonian paleontology ond stratigraphy, Quartz Spring area, Inyo ounty, California: Univ. California, Pubs. in Geol. Sciences, v. 38, 89–152.

Merriam, C. W., 1940, Devonian stratigraphy and paleontology of the Roberts Mountains Region, Nevada: Geol. Soc. America Special Paper 25, 114 p.

Merriam, C. W., 1963o, Geology of the Cerro Gordo mining district, Inyo County, California: U. S. Geol. Survey Prof. Poper 408, 83 p.

Merriam, C. W., 1963b, Paleozoic rocks of Antelope Valley, Eureka and Nye Counties, Nevada: U. S. Geol. Survey Prof. Paper 423, 67 p.

Merriam, C. W., and Hall, W. E., 1957, Pennsylvanian and Permian rocks of the southern Inyo Mountains, California: U. S. Geol. Survey Bull. 1061-a, p. 1–15.

McAllister, J. F., 1952, Rocks and structure af the Quartz Spring area, northern Panamint Range, California: California Division Mines Spec. Rept. 25, 38 p.

McAllister, J. F., 1956, Geology of the Ubehebe Peak quadrangle, California: U. S. Geol. Survey Quad. Map GQ-95.

Nelson, C. A., 1962, Lower Cambrian-Precambrian succession, White-Inyo Mountains, California: Geol. Soc. Amer. Bull., v. 73, p. 139–144.

Nolan, T. B., 1929, Notes on the stratigraphy and structure of the northwest portion of the Spring Mountains, Nevada: Amer. Jour. Sci., 5th series, v. 17, p. 461–472.

Nolan, T. B., Merriam, C. W., and Williams, J. S., 1956, The stratigraphic section in the vicinity of Eureka, Nevada: U. S. Geol. Survey Prof. Paper 276, 77 p.

Palmer, A. R., 1965, Trilobites of the Late Combrian Pterocephaliid Biomere in the Great Basin, United States: U. S. Geol. Survey Prof. Paper 493, 105 p.

Palmer, A. R., and Hazzard, J. C., 1956, Age and correlation of Cornfield Springs and Bonanza King Formatians in southeastern California and southern Nevada: Amer. Assoc. Petrol. Geologists Bull., v. 40, p. 2494–2499.

Ross, D. C., 1965, Geology of the Independence quadrangle, Inyo County, Califarnia: U. S. Geol. Survey Bull. 1181-o, 64 p.

Ross, R. J., Jr., 1964a, Relotions of Middle Ordovician time and rock units in the Basin Ranges: Amer. Assoc. Petrol. Geologists Bull., v. 48, p. 1527–1554.

Ross, R. J., Jr., 1964b, Middle and Lawer Ordovician Formations in southernmost Nevada and adjacent California: U. S. Geol. Survey Bull. 1180-c, p. c1–c100.

Walcott, C. D., 1908, Cambrian sectians of the Cordilleron orea: Smithsonian Misc. Coll., v. 53, p. 166–230.

Westgate, L. G., and Knopf, Adolf, 1932, Geology and ore deposits of the Pioche district, Nevado: U. S. Geol. Survey. Prof. Paper 171, 79 p.

Wheeler, H. G., 1948, Late Pre-Cambrian-Cambrian stratigraphic cross section through southern Nevada: Nevada Univ. Bull., v. 42.

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